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W. H. M. CHRISTIE, M.A., F.R.S., President, in the Chair.

The Rev. Charles Douglas Percy Davies, M.A., Ringmer, near Lewes,

was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended :—

Edward Carpmael, B.A., late Scholar of St. John's College, Cambridge, Fellow of the Institute of Patent Agents, Assoc. Inst. C.E., The Ivies, St. Julian's Farm Road, West Norwood, S.E. (proposed by Warren de la Rue); and

James George Petrie, 15 Mercers Road, Holloway, N., Journalist (proposed by A. Cowper Ranyard).

Preuves de la nutation diurne; mode d'observation propre à la mettre en évidence en une seule soirée. Par F. Folie, Directeur de l'Observatoire royal de Bruxelles.

(*Communicated by the President.*)

Pendant l'année 1888, j'ai recherché les méthodes qui sont les plus propres à manifester le mouvement diurne de l'axe de la croûte terrestre, et à en déterminer les constantes, et j'ai appliqué ces diverses méthodes à des observations faites en différents lieux.

Ces procédés peuvent se diviser en deux classes, selon qu'ils sont fondés sur des observations faites en deux lieux, distants, autant que faire se peut, de 6^h en longitude, ou sur des observations faites en un même lieu.

Parmi les premiers, je signalerai particulièrement à l'attention des astronomes le procédé qui consiste à déterminer les constantes de la nutation diurne par la comparaison des catalogues de deux observatoires différents ; j'ai fait choix, dans ce but, des nouveaux catalogues de Paris, de Poulkova et de Bruxelles, que j'ai comparés à ceux de Washington.

Si un astronome voulait effectuer la détermination des constantes de la nutation diurne au moyen de la comparaison d'autres catalogues de deux observatoires situés à peu près à 6^h de distance en longitude, voici les formules dont il devrait faire usage.

$\Delta^2\alpha$ et $\Delta^2\delta$ désignent les différences en A.R. et D. d'une même étoile déterminée dans les deux observatoires (occid., orien.), l leur différence de longitude, c la somme cot $\omega + 0''4354$, ω l'obliquité de l'écliptique, ϵ l'erreur accidentelle de chacune des différences individuelles :

$$(1)\quad \Delta^2\alpha + (c \sin 2\alpha + \tan\delta \cos\alpha)x + [-c\cos 2\alpha + \tan\delta \sin\alpha]\, y = \epsilon ;$$

$$(2)\quad \Delta^2\delta + \sin\alpha x - \cos\alpha y = \epsilon.$$

On peut appliquer isolément le système des équations (1) ou celui des équations (2) à un grand nombre d'étoiles, et chercher x et y par la méthode des moindres carrés. On peut aussi appliquer simultanément les systèmes (1) et (2).

Connaissant x et y on aura $\tan 2L_m = \frac{x}{y}$, L_m désignant la longitude orientale du premier méridien par rapport au méridien mitoyen entre les deux observatoires et le coëfficient de la nutation diurne sera égal à

$$\frac{x}{2''312 \sin l \sin 2L_m} \text{ ou à } \frac{y}{2''312 \sin l \cos 2L_m}.$$

Je reviendrai ci-dessous sur un autre procédé, qui permet de démontrer, en une seule nuit, l'existence de la nutation diurne.

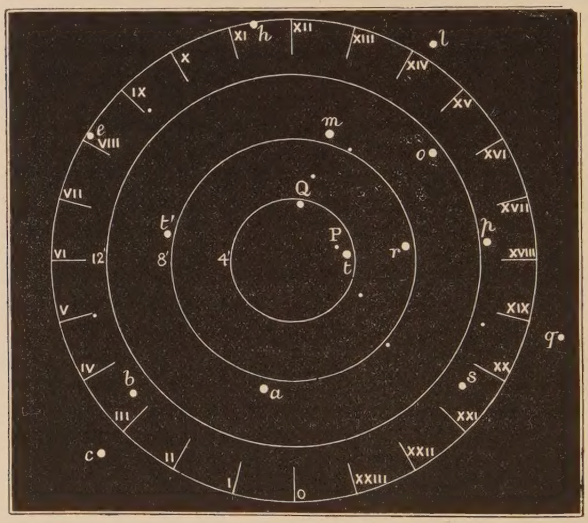
Mais auparavant, je crois utile de signaler aux astronomes les résultats des différentes déterminations qui ont éte faites jusqu'à ce jour.

	Méthodes.	Observatoires.	Nd	Longitude E. de Paris. h m
	Comparaison des catal. en A.R.	Paris–Washington	0,0885 ± 0,0084	5 31 ± 2m,8
	„ „ D.	„	0,508	4 26
	„ „ A.R.	Poulkova–Washington	0,1655 ± 0,006	8 22 ± 9m
	„ „ D.	„	0,2353 ± 0,006	8 36 ± 1m
	„ „ A.R.	Bruxelles–Washington	0,071	12 27,5
	„ des A.R. de δ *Ursæ Min.*	Paris–Washington	0,056	8 52
	Observation de la Polarissime	Kieff	0,209	9 19
	„ α *Ursæ Min.*	Harvard College	0,077	9 29
	„ 117 Pol. Zone	Bonn	0,136	11 1
	„ 297 „	„	0,22	12 7
	„ λ *Ursæ Min.*	Bruxelles	0,10	10 25
	„ α „	Poulkova	0,18	11 45
	„ δ „	„	0,32	8 41
	„ α „	Greenwich	0,12	10 17
	„ α „	Washington	0,17	11 36
	„ σ *Octantis*	Cordoba	0,11	10 17
	„ α *Lyræ*	Washington	0,095	8 48
2	Observations de *t* et Q (26 sept.)	Cointe (Liège)	0,19	9 43
4	„ de P (2 déc.)	„	0,45	11 26
2	„ de P et Q (4 déc.)	„	0,30	4 21
2	„ „ (7 déc.)	„	0,20	10 37

Ces résultats sont, certes, suffisamment probants pour décider tout astronome à admettre, comme absolument certaine, l'existence de la nutation diurne.

On a vu, en partie, dans les derniers exemples donnés, combien il est aisé d'en vérifier l'existence, j'allais dire d'en déterminer les constantes, par des observations, faites à 6^h environ d'intervalle, d'une ou de deux étoiles très voisines du pôle.

Aussi, je ne doute pas que les observatoires, qui possèdent une lunette méridienne assez puissante, ne s'empressent de poursuivre, en même temps que moi, ces observations.



Carte des Circompolaires à 15′ du Pôle.

La petite carte ci-jointe, dans laquelle les lettres minuscules sont celles employées par Carrington, permettra de trouver immédiatement les trois étoiles les plus propres à la détermination dont il s'agit, *t*, P et Q.

Je ferai remarquer que j'ai cherché, pendant les mois d'octobre et de novembre, à effectuer cette détermination par l'observation des deux étoiles *t* et *t'*, situées à 12^h environ de distance en A.R., ce qui serait très avantageux en théorie ; mais que mes observations ont toutes conduit à des résultats beaucoup trop forts pour la constante de la nutation diurne. J'attribue ce mauvais résultat à ce que l'étoile *t'* éloignée de 8′·5 environ du pôle, était située, dans l'une des observations, vers l'extrémité du champ, et qu'il s'y produisait une altération dans la position de l'image de l'étoile, fait qui semble avoir été constaté déjà par M. Loewy.*

* A Bruxelles, même au cercle méridien de Repsold, de 6 pouces d'ouverture, on ne voit que très difficilement l'étoile *t*, absolument pas P et Q, probablement à cause de l'éclairage de l'atmosphère par le gaz de la ville.

A moins donc de faire des recherches très précises sur la distance *réelle* du fil mobile au centre du réticule, lorsqu'il en est éloigné de plus de 3′, il faut s'astreindre à ne pas observer des étoiles plus éloignées du pôle.

Parmi les trois étoiles que j'ai trouvées dans le voisinage du pôle, l'une seulement, *t*, est de $10\frac{1}{2}$ grandeur environ, les deux autres P et Q sont de 12^{e} à 13^{e} seulement.

A la rigueur, on pourrait se borner à observer la première ; on a vu, par l'exemple du 2 décembre, que, des observations d'une seule étoile, on peut déduire les constantes de la nutation diurne. Mais il est plus expéditif, et plus sûr, d'en observer plusieurs à la fois.

Ce procédé offre le grand avantage d'éliminer, pour ainsi dire entièrement, toutes les erreurs de la collimation, d'azimuth, d'inclinaison, et de déviation de la verticale.

Je me suis borné à l'observation des étoiles P et Q en azimuth, n'ayant pu modérer suffisamment l'éclairage des fils horizontaux du réticule pour pouvoir pointer ces étoiles très faibles, en déclinaison.

Ce sont les formules relatives à ce cas que je communiquerai ici. Celles qu'on pourrait employer, dans le cas où l'on aurait fait des observations de la déclinaison de l'étoile, sont d'un usage plus simple, et les astronomes les connaissent.

Voici, d'abord, les formules dont je fais usage pour déduire les A.R. de l'étoile de deux observations azimutales.

De l'équation connue—

$$\tan\delta\cos\phi = \sin\phi\cos(t-\alpha) - \sin(t-\alpha)\cot A \quad . \quad . \quad . \quad (1)$$

dans laquelle ϕ désigne la latitude, t l'heure sidérale du lieu et de l'instant de l'observation, α, δ, A l'A.R., la D. et l'azimut de l'étoile, on tire d'abord, en l'appliquant à deux observations consécutives, et en commençant par négliger le terme en sin ϕ, qui est très petit en général, vis à vis des deux autres, pour des étoiles distantes de 3′ environ du pôle :—

$$\frac{\sin(t_1-\alpha_1)}{\sin(t_2-\alpha_2)} = \frac{\tan A_1}{\tan A_2},$$

et de là,

$$\tan\left(\frac{t_1+t_2}{2}-\alpha\right) = \tan\frac{t_2-t_1}{2}\ \frac{\sin(A_2+A_1)}{\sin(A_2-A_1)} \quad . \quad . \quad (2)$$

Cette équation donne la moyenne α des A.R. de l'étoile aux deux instants de l'observation.

On peut maintenant appliquer l'équation (1) au calcul des valeurs de la déclinaison de l'étoile à ces deux instants.

Si l'on pose

$$\tan q = \tan(t-\alpha)\cot A\sec\phi \quad . \quad . \quad . \quad . \quad . \quad (3)$$

on aura, en effet,

$$\tan\delta = \frac{\cos(t-\alpha)\sin(\phi-q)}{\cos\phi\cos q} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

De cette équation (4) on tirera les valeurs de δ pour les deux observations.

Enfin, faisant

$$\frac{\cot A}{\sin \phi} = \cot A^1,$$

on tirera de l'équation (1)

$$\sin (A^1 - t + \alpha) = \sin A^1 \tan \delta \cot \phi; \quad . \quad . \quad . \quad . \quad (5)$$

Cette dernière équation, appliquée également aux deux observations, donnera les deux valeurs correspondantes de l'A.R. de l'étoile.

La différence de ces deux valeurs fournira une relation entre les deux constantes de la nutation diurne, savoir, son coëfficient N_d, et la longitude orientale L du premier méridien par rapport au lieu de l'observation.

Si l'on combine de la même manière la seconde observation avec la troisième, on aura une seconde équation analogue, et les deux inconnues seront déterminées.

Si l'on désigne par $\Delta\alpha$ la différence des A.R. observées (à 6^h environ d'intervalle), par l cet intervalle de temps, par m et n respectivement les expressions $\cot \epsilon + \sin \alpha \tan \delta$ et $\cos \alpha \tan \delta$, par Σ_1 et Σ_2 des fonctions des arguments de la nutation, dont l'expression sera donnée ci-dessous, les équations à former, qui se déduisent de ma théorie de la nutation diurne, sont, si l'on néglige les termes qui ne renferment pas tan δ;

$$\Delta\alpha = 2 \sin l \tan \delta \left\{ \begin{array}{l} + [\Sigma_1 \sin (\alpha + l) - \Sigma_2 \cos (\alpha + l)] y \\ [\Sigma_1 \cos (\alpha + l) + \Sigma_2 \sin (\alpha + l)] x \end{array} \right\} . \quad . \quad . \quad (7)$$

Dans cette équation—

$$x = N \sin 2L; \quad y = N_d \cos 2L;$$

quant aux fonctions Σ_1 et Σ_2, en voici les expressions numériques, dans lesquelles les différents arguments désignent des longitudes moyennes; on y a donné les coëfficients numériques par leurs logarithmes, et laissé de côté ceux, assez nombreux, qui sont inférieurs à 0·01.

$$\begin{array}{l} \Sigma_1 = -[0{\cdot}062716] - [9{\cdot}12682] \cos \Omega + [9{\cdot}89846] \cos 2 \mathbb{C}, \\ \quad - [9{\cdot}11376] \cos (\mathbb{C} - \Gamma^1) + [9{\cdot}18342] \cos (3 \mathbb{C} - \Gamma^1), \\ \quad + [9{\cdot}12574] \cos (2 \mathbb{C} - \Omega) + [9{\cdot}55410] \cos 2 \odot, \\ \Sigma_2 = -[9{\cdot}25466] \sin \Omega + [9{\cdot}93551] \sin 2 \mathbb{C}, \\ \quad + [9{\cdot}22027] \sin (3 \mathbb{C} - \Gamma^1) + [9{\cdot}25207] \sin (2 \mathbb{C} - \Omega), \\ \quad + [9{\cdot}59136] \sin 2 \odot. \end{array} \quad . \quad . \quad . \quad (6)$$

Dans ces expressions les symboles Ω, $\odot$, $\mathbb{C}$, etc., désignent les longitudes moyennes.

Appliquant la méthode qui vient d'être exprimée à la détermination des constantes de la nutation diurne au moyen des

observations des étoiles t et Q faites à Cointe (Liège) les 26–27 septembre 1888.

1888.		Heure sid. h m s	Azim. Obs. ′ ″	
Sept. 26	t	20 19 26	3 29	W
26	Q	20 27 5	5 18	,,
27	t	1 14 0	4 30	,,
27	Q	1 27 45	1 19	E

L'application de la formule (2), qui précède, a donné d'abord,

h m s
pour t, $\alpha = 17\ 25\ 19{\cdot}9$
,, Q, $\alpha = 12\ 36\ 51{\cdot}4$

D'où l'on a déduit, au moyen des formules (3) et (4),

	t	Q
P.D. =	′ ″ 3 13·0	′ ″ 3 47·2

et par les formules (5)

	t	Q
	h m s	h m s
$\alpha =$	17 25 20·77	12 36 37·89
	17 25 58·50	12 36 47·72

correspondantes aux heures sidérales des observations.

D'où l'on tire

t	Q
s	s
$\Delta\alpha = -37{\cdot}73$	$-9{\cdot}83$

Appliquant les formules (6) pour les heures moyennes des observations, on trouve

	h m	Σ_1		Σ_2
Sept. 26	20 23	$-1{\cdot}3894$	et	$+0{\cdot}1909$
27	1 20	$-1{\cdot}4719$		$-0{\cdot}0616$

En employant la formule (7) on établira les deux équations

$$27^{s}{\cdot}73 = 1062{\cdot}8\ y - 2722{\cdot}4\ x$$
$$9^{s}{\cdot}83 = 2594\ y - 110{\cdot}6\ x$$

qui conduiront aux valeurs suivantes :

$N_d = 0''{\cdot}19$ $\quad$ $L = 9^{h}\ 30^{m}$ E. de Cointe
$= 9^{h}\ 43^{m}$ E. de Paris

On voit que trois observations d'une étoile, faites la même nuit, à 6^{h} environ d'intervalle l'une de l'autre, suffisent pour donner les deux équations nécessaires à la détermination des constantes de la nutation diurne.

L'intervalle de 6^h est celui qu'on doit employer de préférence, comme le montre la formule.

Mais j'insiste surtout sur la haute utilité qu'il y aurait à ce que les deux observations extrêmes fussent séparées exactement par un intervalle de 12^h sidérales.

Je ferai voir ultérieurement l'avantage qu'on peut retirer de ces dernières observations, voulant me borner, ici, à la recherche des constantes de la nutation diurne. Je puis pourtant, dès à présent, signaler l'utilité qu'on en peut retirer au point de vue des études sur la réfraction et sur les variations de la latitude.

Ces observations ne peuvent se faire bien complètement que pendant la saison d'hiver.

J'espère que cette note arrivera encore assez tôt à la connaissance des astronomes pour qu'ils puissent expérimenter ce procédé dans la saison actuelle, et je leur serais très reconnaissant, s'ils voulaient bien avoir l'obligeance de me communiquer les azimuts de ces étoiles qu'ils auraient observés à 12^h sidérales d'intervalle.

Au moment où je termine cette note, M. Niesten, astronome à l'Observatoire royal, me remet les résultats qu'il a déduits des observations de la Polarissime, faites à Kieff de juin à août 1879, en employant les formules que j'ai données dans ma théorie des mouvements diurne, annuel et séculaire de l'axe du monde.*

Je consigne ici ces derniers résultats, qui sont tout aussi concluants que les précédents.

Observations de la Polarissime (Kieff).

(1)	17 juin 1879	K = 0″122	L = 104°6	E. de Kieff
(2)	20 „	0·044	96·8	
(3)	21 „	0·104	101·6	
(4)	22 „	0·102	120·6	
(5)	25 „	0·088	98·0	
(6)	1 juillet	0·063	123·8	
(7)	4 „	0·119	178·5	
(8)	7 „	0·095	135·5	
(9)	9 août	0·050	112·2	
(10)	17 „	0·114	136·7	
(11)	18 „	0·128	150·0	
(12)	21 „	0·187	90·6	
	Moyenne	K = 0·101	L = 120	E. de Kieff
			30·5	
			L = 150·5	E. de Greenwich
			= 10^h.	

* M. Niesten s'est servi des A.R. et des déclinaisons des observations distantes d'un certain nombre d'heures d'intervalle dans une même soirée.

The Greenwich Standard Right Ascensions for 1880·0.

By A. M. W. Downing, M.A.

The Greenwich Clock-Star List for 1889 gives the assumed mean Right Ascensions of clock stars deduced from the "Standard Mean Right Ascensions for 1880, January 1, based on 12-hour groups," printed at the end of the Introduction to the Ten-Year Catalogue. The proper motions used are taken from Auwers' "Neue Reduction der Bradley'schen Beobachtungen," for all stars except μ *Andromedæ*, for which Main's proper motion has been used as heretofore. For δ *Sculptoris* the proper motion is taken from the Cape Catalogue 1880, and is the same as that adopted in the British Association Catalogue. A comparison, therefore, of the R.A.'s of the Greenwich Clock-Star List for 1889 with those of the *Berliner Jahrbuch* for the same year will give the systematic differences between the Greenwich Standard Right Ascensions for 1880·0 and those of Auwers' *Fundamental Catalog* (from which the *Berliner Jahrbuch* places are deduced), and may be of sufficient interest to warrant its publication in the *Monthly Notices*.

The Berlin places of μ *Andromedæ* and δ *Sculptoris* have been corrected for the effect of difference in the adopted proper motions, the Greenwich values being used in both cases. The stars common to the Greenwich and Berlin lists have then been arranged in order of declination, and the differences taken. The following table exhibits the individual differences for these stars, taken in the sense Greenwich − Berlin, or correction to the *Berliner Jahrbuch*; and there are added, for comparison, columns giving the differences Greenwich 1880—*Nautical Almanac* 1889, or correction to the *Nautical Almanac*, and Greenwich 1880—Greenwich Clock-Star List for 1888 (the places of which have been brought up to 1889), or correction to the latter Clock-Star List. It will be remembered that the Right Ascensions of these stars in the *Nautical Almanac* for 1889 have been derived, practically, from the Standard Mean Right Ascensions for 1872·0, published in the Introduction to the Greenwich Nine-Year Catalogue, the adopted proper motions being those determined by Main or Stone, whilst the Right Ascensions of the Clock-Star List for 1888 have also been derived from the same Standard Mean Right Ascensions, but with the aid of Auwers' proper motions, except in the above-mentioned cases. The proper motions adopted in the *Berliner Jahrbuch* for 1889 are, of course, those of Auwers, referred to above.

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
α Lyræ	+38·7	−0·047	+0·011	+0·009
μ Andromedæ	37·9	− ·071	...	+ ·015
β Andromedæ	35·0	− ·070	− ·043	− ·031
β^1 Lyræ	33·2	− ·033	+ ·028	+ ·005
ι Aurigæ	33·0	− ·070	+ ·049	− ·013
ζ Herculis	31·8	− ·069	− ·066	− ·038
ε Herculis	31·1	− ·026	...	+ ·005
ρ Bootis	30·9	− ·027	− ·001	+ ·007
ζ Cygni	29·8	+ ·003	+ ·058	+ ·033
ε Andromedæ	28·7	− ·033	...	− ·006
β Tauri	28·5	− ·018	− ·024	+ ·006
α Andromedæ	28·5	− ·016	+ ·024	+ ·017
β Geminorum	28·3	− ·024	+ ·022	+ ·003
6 Cancri	28·1	− ·049	+ ·012	− ·035
μ Herculis	27·8	− ·073	− ·004	− ·033
32 Vulpeculæ	27·6	− ·041	+ ·015	+ ·009
ψ Bootis	27·4	− ·036	− ·034	− ·010
α Coronæ	27·1	− ·035	− ·007	+ ·002
μ Leonis	26·5	− ·036	+ ·034	− ·012
16 Pegasi	25·4	− ·033	− ·022	+ ·004
ι Pegasi	24·8	− ·016	...	− ·004
ε Leonis	24·3	− ·009	+ ·017	+ ·021
μ Pegasi	24·0	− ·016	...	+ ·003
η Tauri	23·8	− ·013	+ ·012	+ ·005
α Arietis	22·9	− ·030	+ ·027	+ ·018
τ Tauri	22·7	− ·007	...	+ ·001
μ Geminorum	22·6	− ·047	− ·057	− ·036
η Geminorum	22·5	− ·035	+ ·018	− ·017
δ Geminorum	22·2	− ·023	− ·057	+ ·003
δ Leonis	21·1	− ·016	− ·003	+ ·009
ζ Geminorum	20·7	− ·052	...	− ·035
η Cancri	20·7	− ·049	− ·002	− ·024
β Arietis	20·3	− ·033	+ ·042	− ·005
α Bootis	19·8	− ·010	+ ·015	+ ·028
γ Herculis	19·4	− ·002	+ ·002	+ ·015
δ Arietis	19·3	− ·025	− ·017	− ·004
η Bootis	19·0	− ·035	− ·035	− ·022
ε Tauri	18·9	− ·057	+ ·009	− ·025

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
83 Cancri	+18·2	−0·023	+0·070	+0·017
τ Bootis	18·0	− ·033	− ·015	− ·004
γ Geminorum	16·5	− ·038	+ ·030	+ ·010
α Tauri	16·3	− ·012	− ·009	·000
γ Serpentis	16·0	− ·015	...	− ·006
α Delphini	15·5	− ·013	...	+ ·012
γ Tauri	15·4	− ·037	− ·020	+ ·010
β Leonis	15·2	− ·006	+ ·010	+ ·003
ε Aquilæ	14·9	− ·047	+ ·051	·000
ν Orionis	14·8	− ·047	− ·055	− ·032
η Piscium	14·8	− ·037	− ·014	− ·010
α Pegasi	14·6	− ·008	+ ·003	+ ·009
γ Pegasi	14·6	− ·042	− ·024	− ·011
α^1 Herculis	14·5	− ·030	+ ·019	+ ·002
ζ Aquilæ	13·7	− ·009	+ ·069	+ ·011
ξ Geminorum	13·0	− ·020	− ·061	− ·033
α Ophiuchi	12·6	− ·019	+ ·058	+ ·013
f Tauri	12·6	− ·041	...	− ·025
α Leonis	12·5	− ·007	+ ·025	+ ·009
α Cancri	12·3	+ ·032	+ ·072	+ ·053
ε Virginis	11·6	− ·033	− ·043	− ·023
ω Aquilæ	11·4	− ·031	+ ·019	− ·010
l Leonis	11·1	− ·043	+ ·012	− ·016
ε Delphini	10·9	− ·024	·000	− ·008
o Leonis	10·4	− ·036	+ ·027	− ·021
γ Aquilæ	10·3	− ·019	− ·012	+ ·014
ζ Pegasi	10·3	− ·020	− ·057	− ·002
ρ Leonis	9·9	− ·047	− ·047	− ·027
κ Ophiuchi	9·5	− ·019	+ ·025	− ·006
β Cancri	9·5	− ·036	− ·031	− ·026
72 Ophiuchi	9·5	− ·011	− ·003	+ ·007
ε Pegasi	9·4	− ·032	− ·046	− ·006
o Virginis	9·3	− ·035	...	− ·021
o Tauri	8·6	− ·045	− ·104	− ·011
π Leonis	8·6	− ·014	− ·017	− ·001
o Piscium	8·6	− ·023	− ·042	+ ·010
α Aquilæ	8·6	− ·026	− ·012	+ ·004
β Canis Min.	8·5	− ·032	− ·021	− ·018

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
χ Leonis	+8·0	+0·024	+0·015	+0·040
ξ^2 Ceti	8·0	−·032	−·001	−·001
α Orionis	7·4	+·001	+·017	+·020
ϵ Piscium	7·3	−·024	−·072	+·014
δ Piscium	7·0	−·035	+·009	·000
ϵ Hydræ	6·8	−·017	+·009	+·017
α Serpentis	6·8	−·037	−·026	−·005
ω Piscium	6·2	−·029	−·035	−·013
β Aquilæ	6·1	−·042	−·046	−·023
α Canis Min.	5·5	+·019	+·098	·000
ι Piscium	5·0	−·032	−·044	−·016
ν Piscium	4·9	−·024	+·023	+·013
α Equulei	4 8	−·009	...	+·008
ϵ Serpentis	4·8	−·014	−·053	+·001
β Ophiuchi	4·6	−·014	+·037	+·018
δ Virginis	4 0	·000	−·050	+·014
α Ceti	3·7	−·008	+·014	+·031
δ Aquilæ	2·9	−·036	+·030	+·008
γ^2 Ceti	2·8	−·041	+·012	+·020
γ Piscium	2·7	−·001	+·046	+·017
β Virginis	2·4	+·022	...	+0·15
λ Ophiuchi	2·2	−·026	...	+·007
τ Virginis	2·1	−·021	−·041	−·015
κ Piscium	+0·6	+·001	+·004	+·019
ζ Virginis	0·0	−·016	−·035	−·008
η Virginis	−0·1	−·030	+·005	−·020
υ Leonis	0·2	−·018	+·024	+·005
δ Ceti	0·2	−·048	...	−·028
δ Orionis	0·4	−·036	−·051	−·010
η Aquarii	0·7	−·021	+·024	+·004
α Aquarii	0·9	−·006	+·052	+·015
θ Aquilæ	1·2	−·006	−·003	+·014
ϵ Orionis	1·3	−·005	+·021	+·017
γ Aquarii	1·9	−·010	+·019	+·020
η Serpentis	2·9	−·008	−·002	+·013
δ Ophiuchi	3·4	−·033	+·016	−·003
μ Eridani	3·5	−·014	−·048	−·010
12 Ceti	4·6	−·050	+·012	−·021

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
θ Virginis	− 4·9	+ 0·014	+ 0·010	+ 0·014
β Aquarii	6·1	− ·036	+ ·012	+ ·005
67 Ceti	6·9	− ·032	+ ·025	+ ·016
o^1 Eridani	7·1	− ·081	− ·012	− ·035
α Hydræ	8·2	− ·034	+ ·023	− ·012
λ Aquarii	8·2	− ·002	+ ·120	+ ·043
β Orionis	8·3	− ·004	+ ·010	+ ·013
θ Aquarii	8·3	− ·037	+ ·024	+ ·028
θ Ceti	8·8	− ·064	− ·021	− ·023
β Libræ	9·0	− ·028	+ ·022	+ ·005
ι Ceti	9·4	− ·012	+ ·068	+ ·019
κ Orionis	9·7	+ ·008	− ·008	+ ·019
ϵ Eridani	9·8	− ·021	− ·004	+ ·005
κ Virginis	9·8	− ·039	...	− ·027
ϵ Aquarii	9·9	− ·004	+ ·043	+ ·029
δ Eridani	10·1	− ·015	...	− ·035
ζ Ophiuchi	10·3	− ·027	− ·033	− ·002
α Virginis	10·6	− ·026	+ ·007	− ·002
θ Canis Maj.	11·9	− ·053	− ·041	− ·033
α^2 Capricorni	12·9	− ·008	+ ·033	+ ·013
γ^1 Eridani	13·8	− ·007	+ ·031	+ ·016
δ Crateris	14·2	− ·001	− ·036	− ·010
β Capricorni	15·1	− ·015	...	+ ·029
γ Canis Maj.	15·5	− ·008	− ·103	− ·033
α Libræ	15·6	− ·012	− ·035	+ ·007
η Ophiuchi	15·6	− ·006	+ ·010	+ ·023
δ^2 Corvi	15·9	− ·065	− ·166	− ·035
μ Hydræ	16·3	− ·038	− ·041	− ·045
δ Capricorni	16·6	− ·023	...	− ·006
β Canis Maj.	17·9	− ·036	...	− ·017
α Leporis	17·9	+ ·001	+ ·023	+ ·060
ρ Capricorni	18·2	− ·057	+ ·042	− ·015
β Ceti	18·6	− ·038	+ ·026	− ·002
ι^1 Libræ	19·4	− ·032	...	− ·003
β^1 Scorpii	19·5	− ·014	− ·012	− ·002
μ Sagittarii	21·1	− ·039	+ ·030	− ·014
ϵ Corvi	22·0	− ·037	− ·031	− ·015
ϵ Leporis	22·5	− ·050	− ·015	− ·021

Name of Star.	Approx. Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1889.	Greenwich Clock-Star List 1888.
	°	s	s	s
β Corvi	−22·8	+0·043	+0·118	+0·043
15 Argûs	24·1	− ·030	− ·024	− ·017
θ Ophiuchi	24·9	+ ·005	+ ·034	+ ·025
h^2 Sagittarii	25·1	+ ·015	− ·003	+ ·003
α Scorpii	26·2	− ·041	− ·039	− ·015
δ Sculptoris	28·7	+ ·001	+ ·004	+ ·001
ϵ Canis Maj.	28·8	− ·011	− ·023	− ·006
α Piscis Aust.	−30·2	− ·014	+ ·027	+ ·003

With a view to discussing the systematic corrections to the star places of the *Berliner Jahrbuch*, the stars have been combined in convenient groups, and the means of the corrections and of the declinations corresponding to each group taken. The mean $\Delta\alpha$'s have then been graphically represented, and a curve drawn through them, from which can be read off the corrections corresponding to any declination between the extreme limits. The following table, in the columns headed I., gives the computed mean corrections and the corresponding quantities as read off from the curve. The curve has been extended, on both sides, beyond the limits of the extreme mean declinations, by making use of the corrections derived from single stars situated beyond those limits. Its course is, as will be readily understood, considerably more uncertain in these parts than it is between Dec. $+33°{\cdot}9$ and $-25°{\cdot}1$. The corrections, read off from this curve, have then been applied, with reversed signs, to the $\Delta\alpha$ for each star; and it is considered that the outstanding differences are those depending on R.A. The stars have therefore been arranged in order of R.A. and combined in groups of 1^h each, and by a graphical representation of the mean corrections, similar to that explained above, we obtain from the curve which has been drawn the values of $\Delta\alpha$, corresponding to the mean R.A. of each group. The resulting quantities are printed in the table of corrections depending on R.A. given below. The corrections, read off from the curve last referred to, have then been applied, with reversed signs, to the $\Delta\alpha$ for each star, arranged in order of declination, which has been used in forming the first approximation to the systematic corrections depending on declination. The residuals may be considered to be free from discordances depending on R.A., and being treated exactly as before, give the second approximation to the values of the systematic corrections depending on declination. This second approximation is given in the following table, in the columns headed II. As the second approximation differs so little from the first, it was not considered necessary to proceed to a further approximation.

Corrections depending on Declination.

Mean Dec.	Mean Δα. I.	Mean Δα. II.	No. of Stars.	Δα (from Curve). I.	Δα (from Curve). II.
°	s	s		s	s
+33·9	−0·052	−0·051	8	−0·052	−0·051
+28·0	− ·033	− ·035	11	− ·036	− ·037
+23·5	− ·023	− ·024	10	− ·028	− ·029
+19·6	− ·030	− ·031	11	− ·027	− ·028
+14·4	− ·022	− ·023	18	− ·026	− ·027
+10·0	− ·027	− ·030	20	− ·024	− ·026
+ 5·0	− ·018	− ·019	21	− ·021	− ·023
− 1·6	− ·018	− ·021	16	− ·021	− ·022
− 8·9	− ·027	− ·027	17	− ·025	− ·026
−16·2	− ·024	− ·026	17	− ·023	− ·025
−25·1	− ·016	− ·019	11	− ·016	−0·019

Corrections depending on Right Ascension.

Mean R.A.	Mean Δα.	No. of Stars.	Δα (from Curve).
h	s		s
0·4	−0·004	9	−0·003
1·5	− ·011	6	− ·009
2·5	− ·009	6	− ·007
3·5	+ ·001	7	− ·005
4·5	− ·011	7	− ·003
5·4	+ ·011	8	·000
6·5	− ·011	10	− ·001
7·6	+ ·007	5	+ ·003
8·5	+ ·007	5	+ ·006
9·5	+ ·001	6	+ ·003
10·5	+ ·002	5	+ ·006
11·5	+ ·015	6	+ ·009
12·5	+ ·001	6	+ ·006
13·6	+ ·005	6	+ ·005
14·6	+ ·006	5	+ ·005
15·6	− ·001	7	+ ·001
16·5	− ·002	8	− ·001
17·4	+ ·002	6	+ ·001
18·4	+ ·001	6	+ ·002
19·5	+ ·001	7	+ ·002
20·5	+ ·004	8	+ ·004
21·6	+ ·005	6	+ ·006
22·6	+ ·009	10	+ ·008
23·5	+ ·007	5	+ ·005

In a paper entitled "On the Star Places of the *Nautical Almanac*," printed in the *Monthly Notices*, vol. xlv. No. 5, there will be found tables giving the systematic corrections to the star places of the *Nautical Almanac*, the *Berliner Jahrbuch*, the *American Ephemeris*, and the *Connaissance des Temps*, all for the year 1883, to reduce them to the system of the *Nautical Almanac* for 1884. The star places of the *Nautical Almanac* for 1883 were derived from the Greenwich First and Second Seven-Year Catalogues, with Main's or Stone's proper motions. Those of the *Nautical Almanac* for 1884 were derived from the Greenwich Nine-Year Catalogue, using the same proper motions. The *Berliner Jahrbuch* places for 1883 were derived from Auwers' *Fundamental Catalog*, using the proper motions of that Catalogue, as were also the Berlin places for 1889, as stated above. These tables of systematic corrections, therefore, in combination with the comparison of the Greenwich R.A.'s for 1889 with those of the *Berliner Jahrbuch* for the same year, enable us to form tables of systematic corrections to the R.A.'s of the *Nautical Almanac* for 1883, the *American Ephemeris* for 1883, the *Connaissance des Temps* for 1883, and the *Nautical Almanac* for 1884, to reduce them to the system of the Greenwich Standard Right Ascensions for 1880·0.

These final tables of systematic corrections are given below. It will be noticed that, except for the considerable difference in adopted equinox,* the Greenwich Standard R.A.'s for 1880·0 approximate closely to those of the *Fundamental Catalog*—more closely, in fact, than they do to those of the *Nautical Almanacs* for 1883 or 1884; a result which appears to be due, partly, to the adoption of Auwers' proper motions in the formation of the Greenwich mean places (the effect of which can be estimated from a comparison of the corrections to the *Nautical Almanac* for 1889 with those to the Greenwich Clock Star List for 1888, given in the first table above), and partly to the gradual elimination of periodic errors from the assumed places of the Greenwich clock-stars, which is being effected by the methods now adopted at Greenwich for the determination of Standard Right Ascensions.

Dec.	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical Almanac 1884.
	Corrections depending on Declination.				
°	s	s	s	s	s
+35·0	−0·061	−0·025	−0·082	+0·020	+0·001
30·0	− ·042	− ·017	− ·058	+ ·012	·000
25·0	− ·031	− ·020	− ·042	+ ·012	− ·010
20·0	− ·028	− ·014	− ·040	+ ·016	− ·013
15·0	− ·027	− ·006	− ·043	+ ·020	− ·012

* The difference between the equinox of the *Fundamental Catalog* and that now adopted at Greenwich is pointed out in a paper on "The Greenwich Standard RightAscensions," published in the *Monthly Notices*, vol. xl. No. 3.

	Berliner Jahrbuch 1889.	Nautical Almanac 1883.	American Ephemeris 1883.	Conn. des Temps 1883.	Nautical Almanac 1884.
		Corrections depending on Declination.			
Dec. °	s	s	s	s	s
+10·0	−0·026	−0·002	−0·046	+0·003	−0·009
+ 5·0	− ·023	·000	− ·046	− ·009	− ·010
0·0	− ·022	+ ·008	− ·042	− ·009	− ·010
− 5·0	− ·023	+ ·017	− ·039	− ·006	− ·006
10·0	− ·026	+ ·018	− ·043	− ·006	− ·008
15·0	− ·025	+ ·021	− ·044	− ·002	− ·005
20·0	− ·023	+ ·022	− ·042	− ·003	− ·002
−25·0	− ·020	+ ·024	− ·037	− ·011	+ ·006
		Corrections depending on Right Ascension.			
R.A. h	s	s	s	s	s
0·0	+0·001	+0·039	+0·003	+0·037	+0·026
1·0	− ·007	+ ·022	− ·006	+ ·022	+ ·005
2·0	− ·008	+ ·009	− ·007	+ ·009	− ·004
3·0	− ·006	·000	− ·004	− ·009	− ·004
4·0	− ·004	− ·013	·000	− ·036	− ·009
5·0	− ·002	− ·022	+ ·002	− ·053	− ·010
6·0	− ·001	− ·030	− ·001	− ·055	− ·013
7·0	·000	− ·029	− ·003	− ·042	− ·012
8·0	+ ·004	− ·009	+ ·002	− ·016	+ ·006
9·0	+ ·005	+ ·021	+ ·006	− ·004	+ ·030
10·0	+ ·005	+ ·022	+ ·009	− ·005	+ ·028
11·0	+ ·008	+ ·007	+ ·012	− ·009	+ ·011
12·0	+ ·007	− ·013	+ ·006	− ·019	− ·009
13·0	+ ·005	− ·025	+ ·001	− ·022	− ·017
14·0	+ ·005	− ·027	− ·002	− ·018	− ·011
15·0	+ ·004	− ·021	− ·004	− ·011	− ·006
16·0	·000	− ·014	− ·006	− ·003	− ·006
17·0	·000	·000	− ·001	+ ·008	− ·001
18·0	+ ·002	+ ·019	+ ·006	+ ·022	+ ·012
19·0	+ ·002	+ ·038	+ ·005	+ ·031	+ ·021
20·0	+ ·003	+ ·051	+ ·003	+ ·038	+ ·032
21·0	+ ·005	+ ·058	+ ·003	+ ·044	+ ·040
22·0	+ ·007	+ ·060	+ ·005	+ ·047	+ ·043
23·0	+ ·007	+ ·053	+ ·007	+ ·046	+ ·039

Blackheath: March 1889.

On a Graphical Method for determining the Orbit of a Binary Star.

By Professor S. Glasenapp.

(*Communicated by Herbert Sadler.*)

The problem of determining the elements of a binary star consists of two separate parts: (1) to obtain the apparent orbit from a series of given observations, and (2) to compute the elements of the true orbit, the apparent orbit being given. Both parts can be solved by graphical and analytical methods.

Between the true and apparent orbit exists a geometrical relation which furnishes the means for obtaining one orbit when the other is given; this is a purely geometrical problem.

The apparent orbit is never known; we can only determine the probable apparent orbit of the component stars. Each computer tries to obtain the most probable orbit.

The general equation of an ellipse, being a curve of the second degree, is—

$$\alpha x + \beta y + \gamma x^2 + \delta xy + \epsilon y^2 + 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where x and y are the rectangular co-ordinates of the *comes* relative to the principal star which coincides with the origin of the co-ordinates. The plane of co-ordinates is perpendicular to the line of sight.

The coefficients of the equation (1) for an ellipse must satisfy the well-known conditions—

$$\begin{gathered}(\beta\delta - 2\alpha\epsilon)^2 - (\delta^2 - 4\epsilon\gamma)(\beta^2 - 4\epsilon) > 0, \\ \delta^2 - 4\epsilon\gamma < 0.\end{gathered} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

I should add to them the two following :—

$$\gamma < 0 \text{ and } \epsilon < 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

which represents that the principal star lies in the inner part of the ellipse—i.e. that the ellipse obtained intersects the two co-ordinate axes of x and y on opposite sides of the principal star. If the conditions (3) are not fulfilled all the parts of the ellipse lie outside the principal star. In this case, in determining the elements of the true orbit by the usual methods, we shall obtain imaginary elements.

Let us now consider a very simple method for determining the coefficients α, β, γ, δ, and ϵ of the general equation (1).

Let us assume that the apparent ellipse is drawn with such care as is generally employed in graphical methods.

If we put $y=0$, the equation (1) will be reduced to an equation of the second degree in x—

$$\alpha x + \gamma x^2 + 1 = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

whose roots are the co-ordinates of the two points where the

apparent ellipse intersects the axis of x. These roots being x_1 and x_2, we obtain

$$\alpha = -\frac{x_1 + x_2}{x_1 x_2}; \quad \gamma = \frac{1}{x_1 x_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

If, further, we put $x=0$, we obtain an analogous equation in y—

$$\beta y + \epsilon y^2 + 1 = 0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

whose roots are the co-ordinates of the two points where the apparent ellipse intersects the axis of y. These roots being y_1 and y_2, we obtain

$$\beta = -\frac{y_1 + y_2}{y_1 y_2} \qquad \epsilon = \frac{1}{y_1 y_2} \text{ *} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

If, therefore, we measure with compasses the co-ordinates x_1, x_2, y_1, and y_2 of the four intersecting points of the apparent ellipse with the co-ordinate axes, we obtain immediately, by means of the formulæ (5) and (7), the values of the four coefficients α, β, γ, and ϵ.

For the determination of δ we must take a fifth point. Let its co-ordinates be x_3 and y_3; then, from the general equation (1), we obtain

$$\delta = -\frac{1 + \alpha x_3 + \beta y_3 + \gamma x_3^2 + \epsilon y_3^2}{x_3 y_3} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

From the form of this equation we can see that the most accurate determination of δ will be obtained in the case when the divisor $x_3 y_3$ has its maximum value. It is always possible to choose, without any calculation, such a point on the apparent ellipse whose co-ordinates very nearly satisfy this condition. As a check we can take a second point on the opposite side of the apparent ellipse, and obtain a second value of δ.

The mean of both values will be more accurate and more free from accidental errors which may have been made in drawing the apparent ellipse.

It is easy to see that the calculation of the coefficients α, β, γ, δ, and ϵ by means of the formulæ (5), (7), and (8) is very simple. The results are quite independent of the errors which may occur in drawing secondary ellipses, circles, and lines. This is an advantage which is worthy of attention. Further, all the calculation can be made in 10 to 15 minutes of time.

To illustrate this method, I will here give a numerical example. I take the excellent "Handbook of Double Stars" of Edw. Crossley, F.R.A.S., Joseph Gledhill, F.R.A.S., and James M. Wilson, M.A., F.R.A.S., and select the example of a graphical determination of the orbit of *Castor*.

On Plate II., p. 116, of this "Handbook," we find the apparent ellipse of *Castor*. From this drawing we take the following co-ordinates of the four points of intersection of the apparent

* The co-ordinates y_1 and y_2, and also x_1 and x_2, must have opposite sings; therefore γ and ϵ must be negative.

ellipse with the axes of x and y. The positive end of the axis of x is directed to the north ($\theta=0°$), the positive end of the axis of y is directed to the point whose position is determined by $\theta=90°$.

We have—

$$\text{for } y=0 \qquad x_1=+111^{mm}\cdot 8 \qquad x_2=-233^{mm}\cdot 0,$$
$$\text{for } x=0 \qquad y_1=+170^{mm}\cdot 4 \qquad y_2=-115^{mm}\cdot 6,$$

whence we obtain—

$$\log\alpha=\log\left[-\frac{x_1+x_2}{x_1x_2}\right]=7\cdot 6676_n-10,\quad \log\beta=\log\left[-\frac{y_1+y_2}{y_1y_2}\right]=7\ 4444-10$$

$$\log\gamma=\log\left[\frac{1}{x_1x_2}\right]=5\cdot 5842_n-10,\qquad \log\epsilon=\log\left[\frac{1}{y_1y_2}\right]=5\cdot 7056_n-10.$$

To obtain δ we choose a point which is determined by the co-ordinates—

$$x_3=-200^{mm} \qquad y_3=-75^{mm},$$

which gives us—

$$\log\delta=\log\left[-\frac{1+\alpha x_3+\beta y_3+\gamma x_3^2+\epsilon y_3^2}{x_3y_3}\right]=4\cdot 8230-10.$$

To check this we take another point on the opposite side of the ellipse, whose co-ordinates are—

$$x_4=+50^{mm} \qquad y_4=+150^{mm},$$

and thus obtain a second value of $\log\delta=4\cdot 8549$. The logarithm of the mean of these two values of δ is equal to—

$$\log\delta=4\cdot 8392-10.$$

Thus we have obtained the values of the coefficients α, β, γ, δ, and ϵ of the equation (1).

This example is a good proof of the facility with which the coefficients α, β, γ, &c. can be obtained by the proposed method.

In investigating the true orbit I always use the very elegant formulæ of the late Russian Professor of the Imperial University at Kazan, M. Kowalsky,* which give the following relations between the elements of the true orbit and the coefficients α, β, γ, &c., of the general equation (1):—

$$\left.\begin{aligned}
&\frac{\tan^2 i}{q^2}\cdot\sin 2\Omega=\delta-\tfrac{1}{2}\alpha\beta\\
&\frac{\tan^2 i}{q^2}\cdot\cos 2\Omega=(\gamma-\epsilon)-\tfrac{1}{4}(\alpha^2-\beta^2).\\
&\frac{2}{q^2}+\frac{\tan^2 i}{q^2}=-(\gamma+\epsilon)+\tfrac{1}{4}(\alpha^2+\beta^2).\\
&e\sin\lambda=-\frac{q}{2}(\beta\cos\Omega-\alpha\sin\Omega)\cos i.\\
&e\cos\lambda=-\frac{q}{2}(\beta\sin\Omega+\alpha\cos\Omega).\\
&a=\frac{q}{1-e^2}.
\end{aligned}\right\}\quad\ldots\quad(9)$$

* These formulæ may be found in the *Proceedings of the Kazan Imp. University* for the year 1873.

where—

i is the inclination of plane of the orbit to the line of sight (plane of xy).

Ω is the position-angle of the node.

e is the eccentricity.

λ is the angle between the node and the periastron $(\pi - \Omega)$.

a is the semi-axis major.

The first and second equations determine the node Ω and $\frac{\tan^2 i}{q^2}$; from the third we obtain $\frac{2}{q^2}$, and hence q and i; then the fourth and fifth equations determine e and λ, and from the last one we obtain the value of a.

The calculation of the elements by these formulæ, as may be seen, is very simple. The geometrical elements can be obtained in half an hour when α, β, γ, δ, and ϵ are given.

For example, we deduce—

$$\log \frac{\tan^2 i}{q^2} \cdot \sin 2\Omega = 5{\cdot}1264$$

$$\log \frac{\tan^2 i}{q^2} \cdot \cos 2\Omega = 4{\cdot}9464$$

$$\log \tan 2\Omega = 0{\cdot}1768$$

$$2\Omega = 56°{\cdot}35 \qquad \Omega = 28°{\cdot}18$$

$$\log \frac{\tan^2 i}{q^2} = 5{\cdot}2060$$

Further—

$$\log \left[\frac{2}{q^2} + \frac{\tan^2 i}{q^2} \right] = 5{\cdot}9846$$

and hence—

$$\log \frac{2}{q^2} = 5{\cdot}9055$$

$$\log q = 2{\cdot}1978$$

$$\log \tan^2 i = 9{\cdot}6015 \qquad i = 32°{\cdot}30$$

$$\log e \sin \lambda = 9{\cdot}4911_n$$

$$\log e \cos \lambda = 9{\cdot}3420$$

$$\log \tan \lambda = 0{\cdot}1491_n \qquad \lambda = 305°{\cdot}35$$

$$\log e = 9{\cdot}5901 \qquad e = 0{\cdot}380$$

and finally—

$$\log a = \log \frac{q}{1 - e^2} = 2{\cdot}2816 \qquad a = 184^{mm}{\cdot}3$$

To convert the value of a into seconds of arc, we take from the "Handbook," on p. 113, the distances on the millimetre scale. We find there that—

$$1238^{mm}{\cdot}2 = 45''{\cdot}07$$

Therefore—

$$a = 184^{mm}\cdot 3 = 6''\cdot 71.$$

Let us compare the geometrical elements of *Castor* thus obtained with those which are found by the authors of the "Handbook":—

Elements of the Handbook.	Glasenapp's Elements.
$a = 6''\cdot 67$	$a = 6''\cdot 71$
$e = 0\cdot 38$	$e = 0\cdot 38$
$\Omega = 28^{\circ}\cdot 25$	$\Omega = 28^{\circ}\cdot 18$
$i = 32\cdot 25$	$i = 32\cdot 30$
$\lambda = 305\cdot 17$	$\lambda = 305\cdot 35$

The elements T and n must be determined by one of the usual methods.

Observatory of the Imperial University,
St. Petersburg.

On the Determination of Normal Places. By Lieut-General J. F. Tennant, R.E., F.R.S.

When it is proposed to correct an approximate orbit by comparing the places deduced from it with a large number of observations, and obtain corrections to the elements by the method of least squares, each observated element of the place would produce an equation of condition. It becomes then necessary to reduce the number of these equations of condition somehow, so as to limit the amount of computation in forming normal equations.

It seems to have been the practice to compute the equation of condition for each observation, and then to take the mean of the equations corresponding to a group of observations, and use it as one equation. Now the use of normal places formed by comparing the observations themselves with an ephemeris from approximate elements is practically universal. Of course the accuracy of these normals is vital. No care in computing can produce trustworthy results unless the normals are accurate, and to make them so a considerable number of observations have to be used, which probably extend over a considerable time. The determination of normal places has been treated of in the fourth volume of Oppolzer's *Lehrbuch*, but his remarks do not seem to me to quite meet the wants of those who have not all his experience and skill to guide their steps.

The difference between the series of places computed from the approximate elements and the true ones may be expressed by a series of the form

$$a + bt^2 + ct^2 + \&c.$$

for a moderate interval of time. If t be the interval between the time for which a normal is desired and that of an observation, a will be the error of the ephemeris at the date of the normal; and the problem is to determine this with the greatest accuracy from a series of fallible places.

The date of the normal should be very near the mean of the dates of the observations employed in determining it. I shall assume that all the observations are of equal value, in which case we shall have the mean of observed errors of ephemeris

$$= a + \frac{\Sigma(t)}{n} b + \frac{\Sigma(t^2)}{n} c + \&c.$$

where n is the number of observations.* When the mean of the dates of observation is taken as that of the normal $\Sigma t = 0$ and $\Sigma(t^p)$ will be small when p is odd; also in all cases the values of b, c, &c. will rapidly decrease, so that we need never take into consideration more than three terms of the series; but it is evident that the value of c as deduced from the observations will largely depend on their errors. If the true value be insensible, then the value of a will be injuriously effected by determining c from the observations and by an amount which may be serious.

Oppolzer's suggestions practically come to these, that when the series of observations cannot be represented sufficiently by two terms of the series we should compare them with more approximate elements; or that, failing such, we should adopt a graphical construction; plot the errors as ordinates, with the time intervals as abscissæ; and, drawing an even curve through the points so as to represent their general run, use the ordinate corresponding to the date of observation as the error of ephemeris. I do not think this procedure will ever satisfy computers; if for no other reason, because the drawing of such an even curve satisfactorily requires an amount of technical skill which can only be attained by long practice; but otherwise the procedure is good, because it forces on one's mind the uncertainty of the result, which one is apt to forget when dealing with the arithmetical procedure, even if one does calculate its probable error.

I would suggest the following considerations as guides as to the use of the term involving t^2 in calculating normal places.

1st. Unless the rate of motion in one direction be rapidly changing, the use of the term involving t^2 will be objectionable.

2nd. If the course of the object in the neighbourhood of the normal place be nearly an arc of a great circle, it is highly probable that the use of the term in t^2 will be injurious.

3rd. If the course of the object be curved, then it may be desirable to determine c; but the first consideration will show for which element of observation it is necessary.

If the greatest accuracy be desirable, then, I think, the best plan would be to get in one of the above ways approximate errors

* Computers will readily make the necessary changes if the observations are of varying weights.

of ephemeris and get first corrections to the elements of the orbit. From these compute not only the places corresponding to the normal date, which are necessary for a further correction, but a place on each side of this, and from the differences between these places and those given by the original ephemeris deduce a value of c. If now we use this in the expression

$$a = \text{mean of errors of ephemeris} - \frac{\Sigma(t)}{n} b - \frac{\Sigma(t^2)}{n} c$$

instead of the value of c from the observations themselves, we shall get a good normal without the labour of computing an entire ephemeris and comparing it with observation.

Thus suppose we compute the place of the object for p days before and after the normal date as well as for that date, and the difference between the ephemeris and these revised places be on the three dates e_1, e_0, e_2, we may put

$$e_1 = a_1 - b_1 p + c p^2$$
$$e_0 = a_1$$
$$e_2 = a_1 + b_1 p + c p^2;$$

whence

$$\tfrac{1}{2}(e_1 + e_2) = a_1 + c p^2, \text{ and}$$
$$c = \frac{1}{p^2} \{\tfrac{1}{2}(e_1 + e_2) - e_0\}.$$

It is needless to compute b_1 and a_1 because an error in b will have little effect; and, moreover, owing to the change in the elements, b and b_1 would not probably be alike; but this value of c will be better than any value deduced directly from the observations.

Of course the corrected normal places would be used for the second correction of elements, and probably it would always suffice to ignore the value of e in getting places for the first investigation.

One advantage of this procedure would be that it would generally suffice to use three places of decimals in the equations of condition, and one less than Oppolzer uses all through the rest of the work, which, indeed, could now be carried out with the slide rule with much saving of labour.

On the Orbit of Comet I. (Sawerthal) of 1888. By Lieut-General J. F. Tennant, R.E., F.R.S.

This comet was discovered at the Cape of Good Hope on the morning of February 19, 1888, by Mr. Sawerthal of the Observatory. Observations were of course very frequent in the earlier part of its course, but fell off greatly as other new objects called for attention, though it continued visible as a faint object till the middle of August of that year.

From Mr. Tebbutt's observations on February 27, March 6, and March 14, I deduced a parabolic orbit; and by comparing this with a large number of observations I deduced normal places of the comet. Of course individually the places were not very accurate; but I believed that by multiplying the observations used I should get fair normals; and, as they came from all parts of the world and were by many observers, I should get rid of those errors which must arise from low magnifying power, difficulty of estimating the centre, and also from the centre of luminosity not always coinciding with the centre of mass.

Each normal place depends on all the published observations I could find during about a fortnight, and, in the case of the last place, observations kindly communicated by the Astronomer Royal and the Radcliffe Observer, which have been since published; some, which seemed manifestly erroneous, I rejected without any attempt at correction. As to the rest, no attempt was made to weight them. Paris mean time has been used in the calculations as most convenient for the *Connaissance des Temps*, but I have now corrected the times of perihelion passage to Greenwich time. The dates &c. of the normals are

No. 1	for Feb.	25·5	P.M.T.	depends on	38	obs.	from Feb.	d 18·6	to Mar.	d 2·6
2	„ Mar.	18·5	„	„	37	„	„ Mar.	13·3	„ Mar.	22·7
3	„ Apr.	9·5	„	„	43	„	„ Apr.	3·6	„ Apr.	17·6
4	„ May	1·5	„	„	40	„	„ Apr.	25·6	„ May	8·6
5	„ May	24·5	„	„	28	„	„ May	17·5	„ May	31·5
6	„ June	13·0	„	„	22	„	„ June	7·4	„ June	19·5
7	„ July	7·0	„	„	18	„	„ June	27·4	„ July	16·4

After this last date I found few observations, and the faintness of the comet made me feel that no confidence could be placed in a normal at a later date.

The first points to be considered when combining into one result observations extending over so considerable a time was the law which should be considered as governing the errors of the ephemeris. Representing this by $a+bt+ct^2$, it is evident that if c be really too small to be determined by the observations, then we should be liable to injure the value of a (which is the correction of ephemeris required) by determining it; on the other hand, if its effect be omitted when really sensible, a would be similarly affected. On examining the apparent course of the comet it seemed that the first five places all lay nearly on a great circle, but that the course was markedly curved later; I therefore concluded that probably c would only require determination for the 6th and 7th places, when, too, the apparent velocity was rapidly changing. I, however, have actually determined a for each date both with and without the use of c. The places with c used I shall call the *first hypothesis*; those without c, the *second*.

The differences between the observed and computed places for each observation on one day were combined to form a mean error at the mean of the times of observation, and to this was assigned a weight equal to the number of observations, and an equation of condition formed to represent it. The solution of these equations by the method of least squares would have been troublesome. I therefore adopted the method described by Leverrier in the latter part of Art. 34, p. 136, of the first volume of the Paris *Annales*, using all the equations to form the a equation, and in forming the b &c. equations rejecting all those in which the coefficient of the unknown quantity is less than $\frac{1}{3}$ of its greatest coefficient; a procedure which saves much trouble without material loss of accuracy.

A first correction of the elements was then obtained on the first hypothesis, with the following result:—

Perihelion Passage 1888, March $17^d{\cdot}002261$ G.M.T.

$$\left.\begin{aligned} \Omega' &= 273^\circ\ 31'\ 25''{\cdot}37 \\ \pi' &= 237\ 14\ 12{\cdot}32 \\ \omega' &= 323\ 42\ 46{\cdot}95 \\ \iota' &= 37\ 46\ 03{\cdot}22 \end{aligned}\right\}$$ Equator and Equinox of 1888·0.

$$\log q = 9{\cdot}8443452$$
$$e = 0{\cdot}9958799.$$

Computing the places at the normal dates, I obtained the following system of errors:—

	$\alpha_o - \alpha_c$		$\delta_o - \delta_c$	
	1st Hyp.	2nd Hyp.	1st Hyp.	2nd Hyp.
1	−1″·6	+ 2″·1	−1″·8	−1″·3
2	+0·6	+ 4·4	+2·2	+1·9
3	+6·1	+ 0·2	−3·3	−0·9
4	+0·4	+ 3·6	+1·3	−2·7
5	−4·9	− 2·2	−5·3	−3·3
6	−5·5	− 9·0	−2·0	−1·4
7	+7·7	+10·7	−4·2	−2·8

These results seemed to me to show that the conclusions I had drawn from the track of the comet were correct, and I proceeded to a second correction of the elements, using the errors of the second hypothesis for the first five dates, and those of the first for the 6th and 7th.

The resulting elements and their probable errors are—

Perihelion Passage, March $17^{d}\cdot001823 \pm 0^{d}\cdot000511$ G.M.T. or
March $17\ 0^{h}\ 02^{m}\ 37^{s}\cdot5 \pm 35^{s}\cdot5$ G.M.T.

$$\left.\begin{aligned} \Omega' &= 273^{\circ}\ 31'\ 26''\cdot29 \pm 6''\cdot13 \\ \pi' &= 237\ 14\ 06\cdot81 \pm 6\cdot13 \\ \omega' &= 323\ 42\ 40\cdot52 \pm 8\cdot67 \\ \iota' &= 37\ 45\ 59\cdot07 \pm 2\cdot83 \end{aligned}\right\} \text{ Equator and Equinox of 1888·0.}$$

$$\log q = 9\cdot8443367 \pm 0\cdot0000042$$
$$e = 0\cdot9958467 \pm 0\ 0000438$$

or if referred to the ecliptic—

$$\left.\begin{aligned} \Omega &= 245^{\circ}\ 22'\ 56''0 \\ \pi &= 245\ 18\ 26\cdot9 \\ \omega &= 359\ 55\ 30\cdot9 \\ \iota &= 42\ 15\ 10\cdot0 \end{aligned}\right\} \text{ Equinox 1888 0.}$$

The period of revolution is $2182\cdot3 \pm 34\cdot6$ years, and the probable error of an element of normal place is $2''\cdot20$ on a great circle; which shows that the mode of determining normals is satisfactory. All the equations of condition were considered of the same weight.

The large inclination of the orbit of this comet places it beyond the action of the outer and larger planets; but it will be seen that the perihelion and node are almost coincident; at the time of perihelion, too, the comet is only 0·027 (in parts of the Earth's mean distance from the Sun) from the orbit of *Venus*; so that if that planet had been in conjunction with the comet when in perihelion, it would have exercised on the comet a force $\frac{1}{2\,7\,0}$ of the solar attraction. It seems possible, therefore, that we owe this member of our system and the present form of its orbit to the action of *Venus* at some remote date.

On the Value of a Scale of Density on a Photograph.

By Captain W. de W. Abney, C.B., R.E., F.R.S.

In the last three eclipse expeditions which have been sent out from England under the auspices of the Royal Society it has fallen to my lot to have a good deal to say on the photographic arrangements, and at the last expedition to Grenada I devised a means of visually ascertaining the comparative brightness of the corona at different points in its surface. It struck me at the time how valuable it would be if, instead of eye measurements, the photographed image could be utilised, as then there would

be a record which could be measured at leisure, and no liability of flurry, which during an eclipse must to some extent always be present. What I propose to show is, how this can be done in a most simple manner by a small preliminary arrangement. I will trace the steps which gradually led me to devise the method I have adopted. There are extant a few instruments for measuring the sensitiveness of photographic plates which go by the name of Spurge's Sensitometer, and one of these is in my hands. It was nearly the first made by the inventor, and is an admirable instrument in many ways. The instrument consists of a series of small chambers side by side, with orifices pierced in the top of each, of different sizes. If the area of one orifice is designated by 1, then the area of the next to it is $2^{\frac{1}{3}}$, of the next $2^{\frac{2}{3}}$, and of the next 2, and so on. Every chamber has an orifice of twice the area of the third previous one. A plate exposed behind such a series of chambers for a fixed time to a uniformly illuminated surface evidently has at different parts of it different intensities of light acting on it, and on development will give a series of densities of deposit, varying according to the intensities of the light acting on it. What the law of density of deposit compared with intensity of light acting is I will not give here, though I have ascertained from experiment and calculation that a definite law does appear to exist, and one which will prove of value, I am led to believe. For my present purpose, however, it will be sufficient to point out the manner in which this density can be accurately measured. For this purpose all that is necessary is to place the negative in front of a condenser with a steady light some little way in rear of it, and form a magnified image of the plate on a white screen.

By placing a mirror a little to one side of such a light a patch of white light can be superposed over this image; and if a rod be placed in the beam of light coming through one of

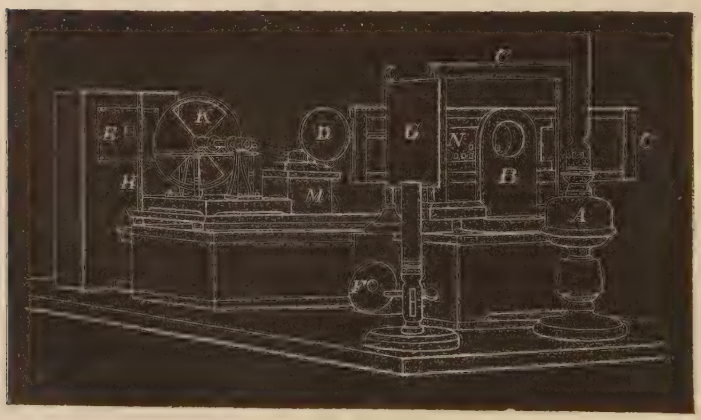


Fig. 1.

these small squares of deposit on the plate, two shadows will be thrown on the screen, one by the direct beam coming through the negative, and the other from the reflected light. The shadows will be illuminated in the ordinary Rumford photometer. A (Fig. 1) is the lamp, B the condenser, C the frame for holding the negative, D the lens which throws the magnified image, N the negative, E the receiving screen, H the rod casting the shadows, G the mirror above alluded to, K the sectors which are to be immediately described. The image of the square of deposit is bordered by a black mark to prevent the eye wandering, and the lens which throws the image is stopped down so as to make the light coming through a part of the plate on which there is no deposit rather less than one-half as bright as the reflected beam. The question is now how the shadows can be equalised. This I find most readily done by reducing the light of the reflected beam by means of rotating sectors which can be opened and closed during rotation. The following description is taken from one of my Cantor lectures recently delivered before the Society of Arts :—

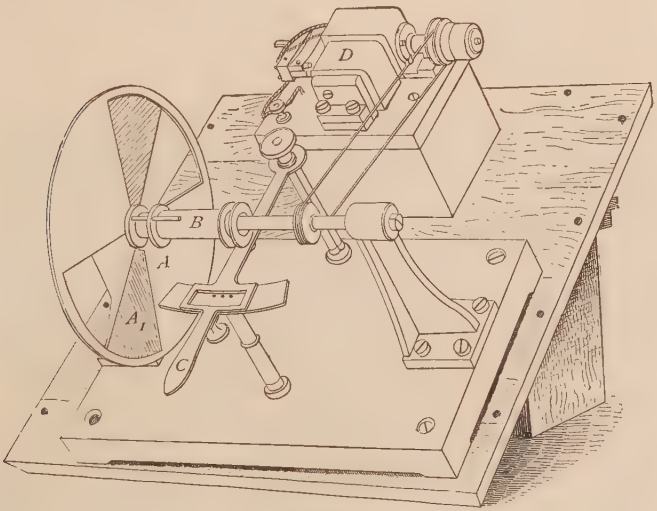


Fig. 2.

The annexed figure (Fig. 2), is a bird's-eye view of the instrument. A A are two sectors, one of which is capable of closing the open aperture by means of a lever arrangement, C, which moves a sleeve in which is fixed a pin working in a screw groove ; D is an electromotor causing the sectors to rotate, and the aperture in the sectors can be opened and closed at pleasure during their revolution by means of the lever C.

Such an instrument, then, puts it in our power to equalise the shadows ; and having seen what aperture of sector is required to

equalise the light passing through a portion of the plate having no deposit, the density of a deposit is measured by the ratio of the aperture required in the latter case to that of the former. Thus, if "no deposit" requires an aperture of sector of 80° to cause equality of light, and a certain deposit requires only 10°, then we know that the deposit cuts off $\frac{7}{8}$ of any light passing through it. A large number of plates exposed in the sensitometer were measured, and the results were so excellent that I went a step further. A crux in photography is to know the sensitiveness of a plate to different parts of the spectrum. This method of measurement gave a ready means of accurately doing this. A spectrum was taken on a plate in the ordinary manner, and by a comparison line-spectrum the position of the different parts of the photographed image was ascertained; but to make the matter complete it became necessary to make a scale of density on the same plate, the exposure value of the scale being known. This was effected by exposing different small parts of the unexposed portion of the plate for varying lengths of time to a light of approximately unvarying intensity. An oil-lamp with an argand burner was found to be sufficient for the purpose. By this means, on development, we had the spectrum (in most cases that of gas-light) to be measured, a comparison spectrum of sodium and lithium, and a series of small squares of varying density, the time of exposure which gave these densities being carefully noted and recorded. This density scale was then measured in the way described, and then the spectrum was marked out in a large number of small portions, and the density of deposit of these bits carefully measured also. The image of the photographed spectrum was much enlarged on the screen, and by substituting a thick knitting-needle for the thick rod one was able to measure the average density of a very small bit of the image without any appreciable error. These measures being obtained, the relative sensitiveness of the plate to the various parts of the spectrum was readily ascertained, and could be plotted.

The scale of "density and time" was laid down on squared paper forming a curve, and then the density of deposit in the photographed spectrum was converted into its *equivalent exposure in time*, and this curve plotted. It might be objected that time of exposure and intensity of light are not interchangeable. I may say, however, that I took careful measures, and find that with the exposures given the one is convertible into the other. Here, then, we have a method of comparing the intensity of light acting on a plate solely by adding a scale as I have indicated. In the same way, by adding a scale to a photograph of the corona taken during an eclipse, a measure of the comparative intensity of light acting to form part of the image can be readily made, and can all be referred to the light of the illuminant with which the scale is made.

In the photographs of the nebulæ such as are produced by Mr. Common, if such a scale were introduced I think their value

would be very much increased, for by this artifice the relative values of the light acting at each part of the plate would be measured in a very satisfactory manner, and a record would be obtained which in time to come could be referred to to ascertain if any change in the relative brightnesses of the different parts had taken place, however small such change might be.

I give one test of the accuracy of the measurement that can be obtained by this plan. I had cut out a star of white card, (Fig. 3) in which equal distances from a fixed radius gave equal decrements of white. This star was fastened against a dead black background and rotated rapidly whilst being photographed. The photograph gave a shaded disc most dense at the centre, and nearly free from deposit at the rim. Had the black reflected no light there would have been no deposit, but as the black ground reflected 4·9 per cent. of white light this had to be taken into account. A scale was impressed on the plate as before described, and measurements of the scale and of the shade made. Fig. 4 shows the density curve of the scale; Fig. 5 the density curve of the disc; whilst Fig. 6 shows the luminosity of the rotating star from calculation and from measurement. I append a table and figures to illustrate the results I obtained. It will be seen that the luminosity of the rotating star as measured from the photograph is the same as the actual luminosity, the measures lying very close to the straight line which is drawn amongst them. The small portion of light

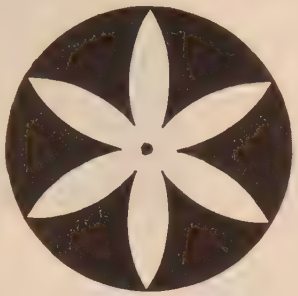


Fig. 3.

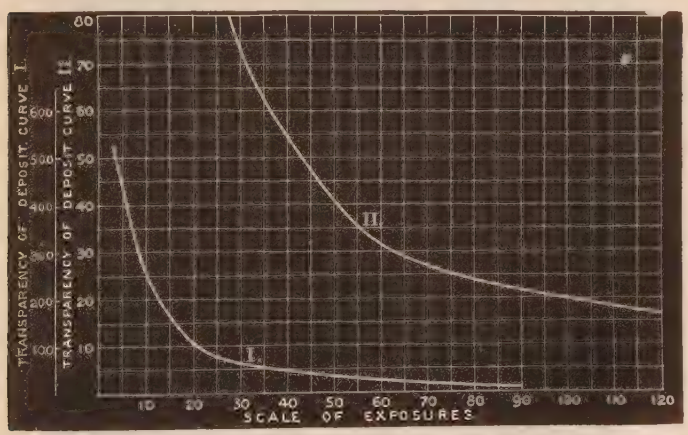


Fig. 4. Curve II. is the same as Curve I., enlarged in scale of ordinates 10 times.

reflected by the black surface is not sufficient to make the actual luminosity differ from a straight line on the scale to which the diagram was drawn, and may therefore be considered as prac-

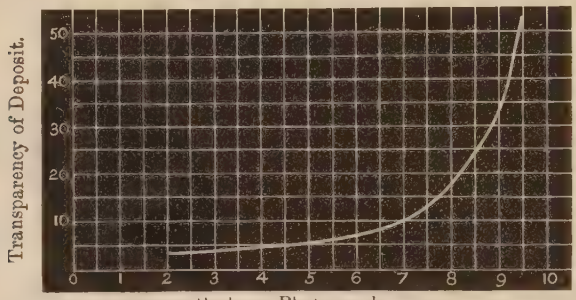


Fig. 5.

tically a straight line. It will be noticed in Fig. 6 that the line drawn through the measured points and the line indicating the visual luminosity meet in a point, as they should

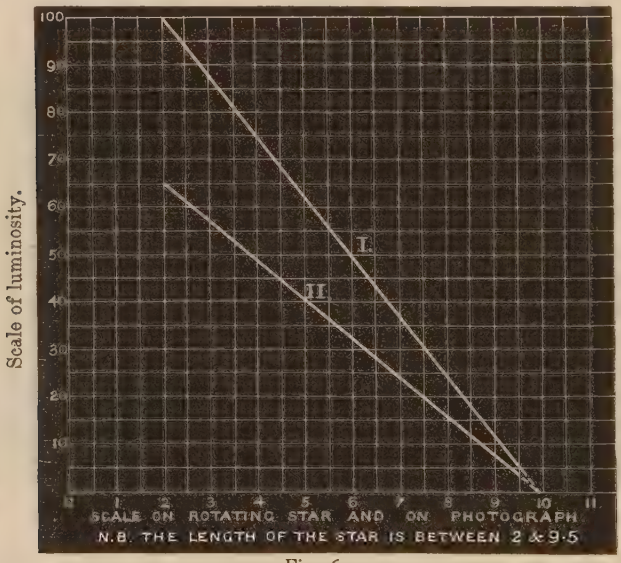


Fig. 6.

I. Luminosity of rotating star. II. Measured luminosity of photograph.

do, though beyond the limits of the star. This shows that the measured and actual luminosities are strictly proportional to one another, which of course they should be. I trust that in future work the value of attaching a density scale to each negative will be appreciated.

Distance from centre of image. inches.	Amount of light reflected from white in %.	Amount of light reflected from black in %.	Total light reflected.	Readings of density.	Mean reading of density.	Proportion of direct light beams.	Adopted reading.	Brightness corresponding to the density from scale meas.	Brightness in %.	
·2	100	...	100	30, 31, 31	30·6	1	30·6	67	100	
·4	100	...	100	31, 31, 30	30·6	1	30·6	67	100	
·6	86·6	·6	87·3	34, 33, 34	33·6	1	33·6	58	86·6	
·8	73·3	1·3	74·6	42, 39, 41, 40	41·0	1	41·0	50	74·6	
·9	66·6	1·6	68·2	47, 47, 47	47·0	1	47·0	45	67·2	
1·0	60·0	2·0	62·0	55, 54, 53	54·0	1	54·0	40	60·0	
1·1	53·3	2·3	55·6	60, 59, 59	54·3	1	59·3	37	55·2	
1·2	46·6	2·6	49·2	67, 66, 67	67·3	1	67·6	32·5	48·5	
1·3	40·0	3·0	43·0	78, 79, 79	78·6	1	78·6	28·0	41·8	
1·4	33·3	3·3	36·6	90, 90, 89	89·6	1	89·6	24·5	36·6	
1·6	20·0	4·0	24·0	20, 20½, 21	20·5	⅛	164·6	16·0	23·9	A second set of sectors with ⅛ total circle of light rotated in front of direct light.
1·7	13·3	4·3	17·6	30, 30, 31, 31	30·5	⅛	242	11·5	17·2	
1·8	6·6	4·6	11·2	40, 41, 40	40·6	⅛	324	8·0	11·9	
1·9	...	5.0	5·0	66, 66, 67	66·3	⅛	530	3·5	5·2	

Scale attached to the Photograph of the Rotating Star.

Square No.	Seconds Exposure.	Readings.	Mean Reading.	Amount of direct light on Screen.	Adopted Reading.	Remarks.
1	3	67, 67, 67	67	$\frac{1}{8}$	536	For these readings a second set of rotating sectors was placed in front of the direct light to reduce it. The direct light was thereby made only $\frac{1}{8}$ of the original light.
2	5	57, 56, 57	56·6	$\frac{1}{8}$	453	
3	10	$32\frac{1}{2}$, $33\frac{1}{2}$, 33	33·0	$\frac{1}{8}$	264	
4	15	22, 23, 22	22·6	$\frac{1}{8}$	181	
5	20	14, 16, 15, 15	15·0	$\frac{1}{8}$	120	
6	30	$8\frac{1}{2}$, $9\frac{1}{2}$, 9	9·0	$\frac{1}{8}$	72	
6	30	72, 71, 71	71·3	1		
7	45	47, 47, 47	47·0	1	47	
8	60	32. 33. $32\frac{1}{2}$	32·5	1	32·5	
9	75	26, 25, 26	25·6	1	25·6	
10	90	23, $23\frac{1}{2}$, $22\frac{1}{2}$	23·0	1	23·0	
11	120	17, $17\frac{1}{2}$, 18	17·5	1	17·5	

Note on the Law of Increase in Diameter of Star Discs on Stellar Photographs, with Duration of Exposure. By H. H. Turner, M.A., B.Sc.

In vol. xl. of the *Proc. Roy. Soc.*, p. 449, Professor Pritchard states that, according to his researches, the area of a star image varies nearly as the square root of the duration of exposure, or the diameter as the fourth root of the duration. He further remarks that Bond in 1858 considered the diameter to vary as the square root of the duration. It is therefore, perhaps, worthy of notice that, in some photographs taken at Greenwich with a Dallmeyer object-glass of 4 inches aperture and 5-foot focus, the diameter of the images seems to vary nearly as the cube root of the duration of exposure through a considerable range—a result intermediate between those of Bond and Pritchard. The following measures of the diameters of star-discs on different plates illustrate this point. The diameters are divided by the square roots, the cube roots, and the fourth roots of the durations, to exhibit the relative merits of the three hypotheses in question. It will be seen that the numbers in the cube-root column are generally nearly constant, while those in the other two decrease or increase. The numbers attached to the plates are merely those of the Greenwich series, for convenience of reference.

Plate 18. Region near α *Aquilæ*. 1887, August 31. Four exposures of 1^m, 5^m, 10^m, and 20^m, at the corners of a square.

Three bright stars. (Mean of magnitudes about 3.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=D$.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
1	23·0	23·0	23·0	23·0
5	38·3	17·1	22·4	25·5
10	50·5	16·0	23·5	28·4
20	64·0	14·3	23·6	30·3

Four medium stars. (Mean of magnitudes about 6.)

1	5·4	5·4	5·4	5·4
5	8·4	3·8	4·9	5·6
10	13·0	4·1	6·1	7·3
20	15·7	3·5	5·8	7·4

Six faint stars. (Mean magnitude 7 or 8.)

The short exposure not registered.

1	—	—	—	—
5	6·8	3·1	4·0	4·5
10	9·2	2·9	4·3	5·2
20	13·2	3·0	4·9	6·3

Plate 22. Region near γ *Piscium.* 1887, October 22. Four exposures of 1^m, 5^m, 10^m, 20^m, at corners of a square. "Sky tolerably good."

Five stars. (Mean magnitude about $4\frac{1}{2}$.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=D$.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
1	8·1	8·1	8·1	8·1
5	12·7	5·7	7·4	8·5
10	15·8	5·0	7·4	8·9
20	18·6	4·2	6·9	8·8

Plate No. 23. *Pleiades.* 1887, October 14. Three exposures of 2^m, 4^m, 15^m. "Sky very clear."

Five stars. (Mean magnitude about 4.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=D$.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
2	23·2	16·5	18·4	19·5
4	29·4	14·7	18·5	20·9
15	42·4	11·0	17·2	21·5

Five stars. (Mean magnitude about 6.)

2	8·9	6·3	7·1	7·5
4	10·8	5·4	6·8	7·7
15	18·9	4·9	7·7	9·6

Plate No. 87. Region near R.A. $19^h\ 14^m$, Dec. $+20°$. 1888, September 19. Exposures, 1^m, 2^m, 3^m, 5^m.

Seven stars. (Mean magnitude about 6.)

Duration of Exposure $=t$.	Mean Diameter of Discs $=D$.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
1	7·6	7·6	7·6	7·6
2	9·2	6·5	7·3	7·7
3	10·8	6·2	7·5	8·2
5	12·2	5·5	7·1	8·1

In the above plates no particular attention was paid to the exact duration of exposure, which may thus be slightly inaccurate, especially in the case of short exposures; and the range of duration does not extend below 1^m. On 1889, March 6, special photographs of *Procyon* were taken, with exposures varying from 5^s to 20^m; but there was much haze in the sky, and often cloud, which interfered with the work. On the first plate exposures of 5^s, 10^s, 15^s, 30^s, and 60^s were secured before clouds came up; and, as it was not possible to resume operations for some time, a second plate was put in. On this exposures of 20^m, 5^s, 10^m, and 15^s were given in this order, before the work was quite stopped by clouds. On development, the exposure of 5^s on this plate was found to have been accidentally distributed into two of nearly equal size. It has been assumed that each of these was roughly $2\frac{1}{2}^s$, though some time must have been lost in transition, and allowance must be made accordingly. The following are the results of four independent measures, by each of two observers, of the various discs of *Procyon* on these two plates:—

First Plate.

Duration of Exposure $=t$.	Mean Diameter of Discs $=D$.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
0·083	18·6	64·4	42·6	34·6
·167	23·5	57·6	42·7	36·8
·250	29·3	58·6	46·6	41·5
·5	33·6	47·5	42·4	40·0
1·0	40·8	40·8	40·8	40·8

The 15^s exposure is very irregular in shape, and obviously anomalous.

Second Plate.

Duration of Exposure $=t$.	Mean Diameter of Discs $=D$.	$\frac{D}{t^{\frac{1}{2}}}$	$\frac{D}{t^{\frac{1}{3}}}$	$\frac{D}{t^{\frac{1}{4}}}$
m	″	″	″	″
0·042	9·9	48·3	28·5	22·0
·042	10·8	52·7	30·9	24·0
·25	20·7	41·4	32·9	29·3
10·0	59·1	18·7	27·5	33·2
20·0	63·5	14·2	23·4	30·1

It thus appears that for large star discs the increase of diameter does not increase quite so rapidly as the cube root of the duration, and tends towards the fourth root. For faint stars, on the other hand (as in the third set of plate 18), the rapidity surpasses the cube root, and tends to the square root. This suggests how both Bond's and Pritchard's results may be true under different circumstances.

Photographic Analyses of the Great Nebula M 42 and 43 and h 1180 in Orion. By Isaac Roberts.

By the term photographic analyses is to be understood the appearances which this nebula presents with exposures of the negatives varying between 5 seconds of time and 205 minutes, and when the details are studied by aid of the gradations of the nebulosity which have been obtained in this manner we are enabled to compare the relative actinic power of the light in different parts of the nebula.

We are not to infer that any given exposure of a plate for, say, 15 minutes, or for any other number of minutes, represents a constant quantity of photographic effect which is always available for accurate comparison with other exposures during corresponding intervals of time, for it is found that the photographic effect generally varies from moment to moment during any exposure of a plate owing to atmospheric absorption or extinction of the light; but by taking a number of photographs and selecting them so as to exhibit small gradations in the density of the nebulosity, we see more of the structure than we probably can by any other method, and this applies with greater force to enlargements than to the original negatives.

In the illustrations now presented,* gradations are shown on seven enlarged photographic plates with eleven exposures of the negatives. The enlargements are to five times the size of the negatives.

PLATE 1.

The negative of which this plate is an enlargement was taken on February 16, 1889, and has upon it five consecutive exposures of 5 seconds, 30 seconds, 1 minute, 3 minutes, and 6 minutes respectively, and they show such of the stars and so much of the nebulosity as on that occasion were imprinted on the film. The four stars which form the trapezium are shown on the first exposure of 5 seconds, and they increase in diameter and in density till in the fifth exposure of 6 minutes they form one image with an irregular outline. The nebulosity begins to appear round θ in the third exposure of 1 minute, and in the 6 minutes' exposure it is well developed and characteristic. It will

* The photographs are placed in the Library.

be observed when the photographs are compared with the drawings of this nebula by Lord Rosse that there are many points of resemblance between them in the outlines as well as in the distribution of the nebulosity, and it is apparent that great care and skill have been exercised in the observing and in the drawing of the details which occupied, as Lord Rosse informs us, "every available hour during the winter months of seven seasons." When the photographic plates are exposed for 15 minutes and upwards these resemblances more or less disappear in the cumulative density of the nebulosity.

Plates 2, 3, and 4.

These three plates were enlarged from negatives taken one on each of the following dates: February 16, 1889, December 18, 1886, and February 20, 1889, with 15 minutes' exposures, and they illustrate the differences in the density of the nebulosity due chiefly to atmospheric causes at the time of exposure.

On comparing these photographs with the well-known photograph taken by Mr. Common, on January 30, 1883, I have not detected by eye observations that any changes in the structure of the nebula have taken place during the interval of six years that has elapsed between them, but the examination should be more carefully made by measurements before full reliance is placed on this statement. It is obvious, if we compare the positions of the stars within the nebula as they are shown on the charts by Lord Rosse and by Bond, that changes in the relative positions of some of them have taken place since the year 1866, and I shall here just refer to one as an illustration. In the trapezium the two stars numbered 65 and 69 on Lord Rosse's chart are shown much closer to each other than the stars numbered 67 and 73, and Bond's chart agrees with Lord Rosse's, whereas in the photographs these pairs are nearly equidistant.

Plates 5 and 6.

The negative of plate 5 was taken on February 18, 1889, with an exposure of 30 minutes, and that of plate 6 on December 24, 1888, with an exposure of 81 minutes. Both photographs show great extensions of the nebula, and M 43 is joined to M 42; *h* 1180 is also well developed with its characteristic dark cross streams.

Plate 7.

The negative was taken on February 4, 1889, with an exposure of 205 minutes, and supplies us with evidence that M 42 and 43 and *h* 1180 form one gigantic nebula. The links joining *h* 1180 with the other portions are shown also on another negative which I took with two exposures upon it, one on January 22, 1889, and the other on February 3. The exposures were of

2 hours and $2\frac{1}{2}$ hours respectively. The evidence and confirmation place it beyond reasonable doubt that the links shown are realities, and though they supply us with vastly extended knowledge of the dimensions, and form, and details of this nebula, yet leave us with unsatisfied desire to see more, and probably to find that the nebula will be shown to have a symmetrical form in external outline, but is in a state of strong internal commotion. Next year we ought to be able to supply the missing links and see it as a finished picture. In the meantime we ought, with all gratitude, to admire the patient, long-suffering endurance of those martyrs to science, who during the freezing nights of many successive winters plotted, with pencil in benumbed fingers, the crude outlines which have been handed down to us as correct drawings of this wonderful nebula, which we can now depict during four hours of clear sky with far greater accuracy than is possible by the best hand-work in a lifetime.

Note on an Apparatus for correcting the Driving of the Motor Clocks of large Equatorials for long Photographic Exposures. By A. A. Common, F.R.S.

In giving long exposures in astronomical photography it is absolutely essential that some means be adopted to prevent any shift of the image on the photographic plate during exposure; for if irregularities in clock-driving, changes due to flexure of instrument, and alterations in apparent position due to refraction are not immediately corrected the photograph will be blurred and the fine detail lost. These irregularities are further complicated in the case of reflectors by changes due to alterations of temperature, and by variations of strains in the mirror as the telescope moves round.

There are obviously two methods by which the image of the object to be photographed can be kept in exactly the same position on the plate during exposure: either the telescope itself must be moved by means of its fine screws for slow motion in right ascension and declination, or the photographic plate must be moved during the exposure. The first method has been adopted by the Paris Conference for the instruments to be used in charting the stars. A finder of 9 inches' aperture is to be attached to each photographic instrument, the optic axes to be parallel; and the stars are to be watched throughout the exposure and any shift immediately checked by the slow-motion screws of the instrument. For small instruments this method is perhaps capable of meeting all the difficulties, for the slow motions can be made to work smoothly; but it is impossible to apply it properly to large and heavy instruments, especially to large reflectors where the parallelism of the finder and the axis of the mirror can never be rigidly maintained.

At the meeting of the Society in November 1884 I briefly referred to the apparatus used with the 3-foot reflector at Ealing for moving the photographic plate during exposure, so as to correct for shift; and a similar arrangement having been made for the 5-foot, a description of that in considerable detail is given here.

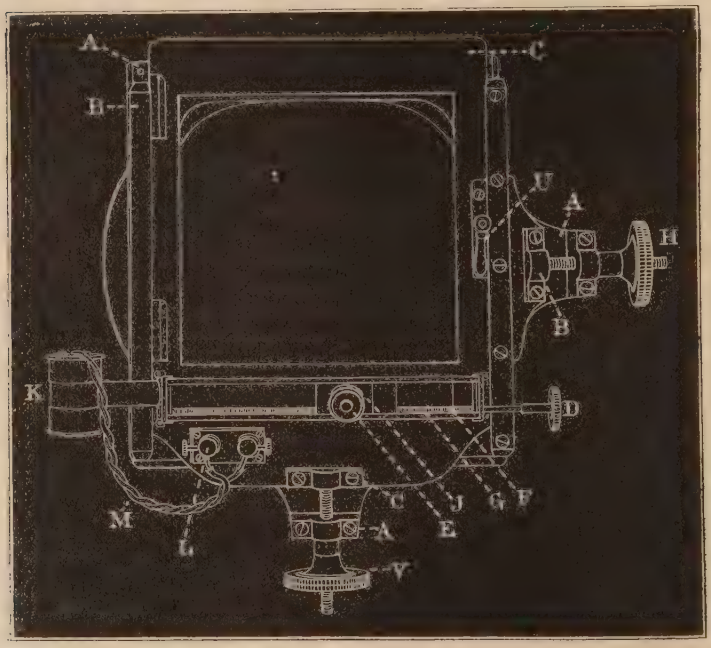


Fig. 1.

Fig. 1 is from a photograph of the apparatus with the plate-carrier detached.

A A A is a plate with three clips behind to attach it rigidly to the eye end of the telescope.

B B is a slide fitting into A and capable of movement in a horizontal direction by means of the fine screw at H.

C C is a slide falling into B and capable of movement in a direction at right angles to the movement of B by means of the fine screw at V.

The dark slide is fitted on to the plate C, a small cam, U, serving to fix the dark slide in position. D is the milled head of a fine screw, F, extending the whole length of the box G, the latter being part of the slide C, and having a glass face.

The plate J slides in grooves above the glass face, and has the eyepiece E screwed into it.

On F is fitted a nut, carrying a small ring (under the glass face) with two cross-wires, the intersection of which is exactly

in the focus of E, and also in the plane of the film of the photographic plate. The cross-wires are illuminated from the side by a small incandescent lamp in K, the light being steady and uniform when the current is supplied from one or two storage cells to the screws L and thence through M to the lamp.

Any one of a line of small pinholes through the bottom of the box G can be uncovered by bringing the cross-wires and eyepiece directly over it. Unless the uncovered pinhole is very small there will be danger of light getting through it and on to the photographic plate, the faintest external light falling on the plate for two or three hours being sufficient to fog it.

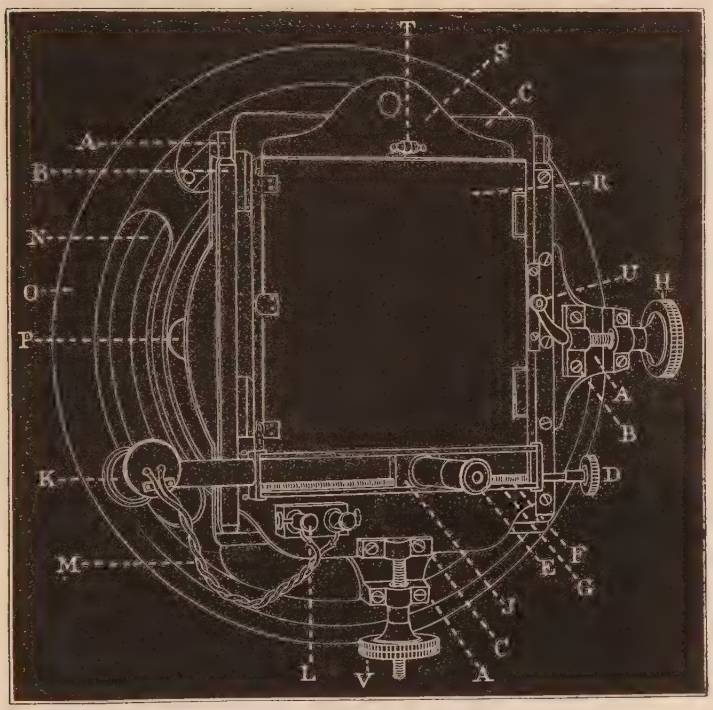


Fig. 2.

Fig. 2 shows the whole eyepiece end of the telescope with the dark slide in position ready for exposure of the plate.

R is the dark slide fitting on to C and fixed to it by U, S is the shutter of ebonite, and T is a small screw which serves to hold the shutter down when the slide is closed, as in figure. and holds it open when the plate is being exposed. N is a ring screwed to the end of the reflector. O is the focussing-wheel, and P one of the three levelling-screws for getting the plate a right angles to the optic axis of the mirror.

In practice, before the exposure is commenced, the apparatus is arranged so that the screw H gives a motion in R.A. to the plate, and V a motion in declination; then any star on the edge of the field is fixed upon and the cross-wires brought directly over it. Throughout the exposure this star is kept under view; the eyepiece being very powerful, the smallest errors become apparent to the eye, and can be corrected at once by the screws. If from any cause it is necessary to discontinue the exposure the plate can be shut up, and the exposure can be recontinued at any time if the guiding star is brought exactly to the cross-wires, for then the plate is in the same position as it was before the interruption. The wires being in exactly the same plane as the film, any alteration of focus can be at once detected in the eyepiece and corrected at once by the focussing-wheel.

Spectroscopic Observations of sundry Stars and Comets, made at the Royal Observatory, Greenwich, chiefly in the years 1887 *and* 1888. By E. W. Maunder.

(*Communicated by the Astronomer Royal.*)

I. γ Cassiopeiæ and β Lyræ.

The object of the following observations was to detect any bright lines in the spectra of these two stars, to watch if such lines varied in brightness, and to determine the wave-length of the bright line near the D lines, supposed to be D_3.

The instruments employed were the half-prism spectroscope, with one half-prism, either in the direct or reversed position, and the single-prism spectroscope, with one large prism of 60°. The dispersions of the three instruments are as follows:—

	A to H.	Power of Eyepiece.
	°	
Half-prism spectroscope, Direct	$18\frac{1}{2}$	14
„ „ Reversed	5	30
Single-prism spectroscope	$4\frac{2}{3}$	10

These were mounted on the South-East equatorial, of 12·8 inches' aperture, and were used either with or without a cylindrical lens before the slit.

γ Cassiopeiæ.

Single-prism spectroscope.

Three bright lines were observed, viz. C, F, and a line near D, supposed to be D_3. These three lines, if seen at all, were seen as bright lines, never as dark.

Date.	Cylindrical Lens before slit. C	D_3	F
1887, Feb. 16	Not seen	Not seen	Very distinct
Dec. 5	*Brilliant*	Not seen	Faint
16	Not seen	Not seen	Faint
1888, Sept. 19	Very bright	Faint	Rather faint

	No Cylindrical Lens. C	D_3	F
1887, Feb. 16	Not seen	Not seen	Very distinct
Dec. 5	*Brilliant*	Not seen	Faint
16	Distinctly seen	Not seen	Not seen
1888, Sept. 19	Very bright	Faint	Rather faint

Half-prism spectroscope, direct. Cylindrical lens before slit.

The C and D_3 lines were not looked for. The F line was observed as follows:—

Date.	Description of Bright F line.
1880, Oct. 1	Brilliant against the background of the continuous spectrum. Broad and diffused at edges. Central condensation.
Nov. 21	Bright.
1881, Dec. 7	Difficult to measure.
1883, Nov. 16	Easily seen.
1884, Aug. 11	Faint.
25	Faint.
Sept. 4	Very faint.
10	Barely visible.
11	Measured. No remarks made.
18	Very faint.
20	Faint. Sharp; well-defined at edges.
1887, Feb. 16	Very faint. Narrow.
Oct. 19	Distinctly a bright line. Broad, and diffused at edges.
1888, Dec. 13	Faint. Narrow, and slightly diffused at edges.

Half-prism spectroscope, reversed. Both with and without a cylindrical lens before the slit.

1887, Dec. 16. Observations made with single-prism spectroscope confirmed.

β Lyræ.

The same three lines—viz. C, D_3, and F—were observed as in the spectrum of *γ Cassiopeiæ*. D_3 was always seen as a bright line if seen at all, but C and F were on one occasion—1888, October 19—suspected to be represented by dark lines.

Half-prism spectroscope, reversed.

Date. 1887.	Cylindrical Lens before slit. C	D_3	F	No Cylindrical Lens. C	D_3	F
Dec. 16	Not seen	Not seen	Not seen	? Bright	Not seen	Not seen

Single-prism spectroscope.

1888.						
Aug. 10	Not seen	Not seen	Not seen	Not seen	Fairly bright	Very faint
Sept. 10	...	...	...	Not seen	Faint	Not seen
19	...	...	...	Not seen	Bright	Not seen
21	Not seen	Very bright	Bright	Bright	Very bright	Bright
Oct. 19	...	...	...	? Dark line	Very faint	? Dark line

The appearance of the three lines as seen on 1888, September 21, was as follows:—

C—Narrow and sharp.

D_3—Very bright, narrow, sharp, and well defined.

F—Rather brighter than C, not nearly so bright as D_3, and somewhat ill-defined at the edges.

The D_3 line, on each occasion when it was seen, appeared to be narrow, sharp, and well-defined.

The following results were obtained for the wave-length of the bright line supposed to be D_3, by measurement of its distance from the D lines as given by a sodium flame:—

Wave-length inferred for the bright line near D.

	1888, Aug. 10; tenth-metres.		1888, Sept. 19; tenth-metres.
	5874·46		5875·76
	5·70		5·82
	3·10		4·58
	1·55		0·80
	3·59		2·79
	6·07		4·65
	5·64		6·88
	2·17		3·16
	3·34		6·13
	3·59		5·33
Mean	5873·92	Mean	5874·59
	Mean of all the measures		5874·26

General Remarks on the Spectra of γ Cassiopeiæ and β Lyræ.

The foregoing observations appear to show that—

(1) The spectra of both stars show bright lines.
(2) These bright lines are variable in brightness.

(3) In the case of γ *Cassiopeiæ*, the three bright lines observed do not vary simultaneously and in the same manner.

(4) In the case of β *Lyræ*, the observations are not sufficient to establish any conclusion, but are not inconsistent with a simultaneous variation of all the three lines observed.

(5) Two of the three lines observed are the C and F lines—the first and second lines, that is, of hydrogen. The measures made of the position of the bright line near D in the spectrum of β *Lyræ* point to its being the so-called "helium" line D_3, and not the fluting of manganese at λ 5869. Its appearance—that of a narrow, sharp, well-defined line—also agrees with this view.

(6) The observations in the case of β *Lyræ* are not sufficient to prove that the variations in the brightness of the D_3 line take place in a similar period to that of the variations in the brightness of the star itself, but they are not inconsistent with such a relation. Arranging the observations in order of the observed brightness of the D_3 line, the following table shows the interval from the next preceding chief minimum :—

Character of D_3.	Date of Observation.		Interval after the last Chief Minimum.
		h	d h
Very bright	1888, Sept. 21	20	7 11
Bright	19	21	5 11
Fairly bright	Aug. 10	22	4 6
Faint	Sept. 10	21	9 9
Very faint	Oct. 19	20	9 14
Not seen	1887, Dec. 16	21	11 17

As the secondary minimum falls $6^d\ 11^h$ after the chief minimum, and the maximum following the secondary minimum about $9^d\ 16\frac{1}{2}^h$ after the chief minimum, the observations are not inconsistent with a maximum brightness of the D_3 line soon after the secondary minimum of the star, followed by a decline to a minimum soon after the second maximum of the star.

(7) The D_3 line is the most conspicuous bright line in the spectrum of β *Lyræ*, but either C or F is the most conspicuous in that of γ *Cassiopeiæ*.

II. Stars with Spectra of the Third Type (Secchi's).

o Ceti (*Mira*) *near Maximum.*

1888, *October* 5.—The spectrum of the star had a remarkably clean appearance, the "zones," or bright interspaces between the dark shaded bands, being quite free from absorption lines. Bands I., V., VII., and VIII. (Dunér's numeration) were very distinct, and all were sharp towards the violet, and shaded towards the red. Band IV. was faint, but appeared to be of the

same character as those just mentioned. Band III. was, as usual, a little shaded at *both* edges and darkest in the middle, but more nearly of a uniform shade than any of the other bands. Band IX. was found to be a rather puzzling object. Being far in the blue, it was a little difficult to make out, but it seemed at times to have its edge about 33 tenth-metres nearer to the red than at others, or at λ 4797 instead of λ 4764. Probably it consisted of two bands close together. Band IX. was faint. Bands VII. and VIII. were the darkest in the spectrum. Beyond Band VIII., towards the violet, the bands were most difficult to see, as they were so faint; but the continuous spectrum itself could be traced an unusually great distance into the violet. The violet end was very free from selective or general absorption. Bright lines at or near F and D_3 were carefully looked for, but none were seen. But a bright line in the violet, evidently the third line of hydrogen, was very distinctly seen, and several measures were obtained of its position, as follow:—

Tenth-metres.		Tenth-metres.
4346		4345
4344		4342
4343		4343
4343		4345
4342	Mean	4343·4
4341		

1888, *December* 1.—The dark bands in the spectrum of *Mira* were of intense blackness, as if slices had been cut clean out of the spectrum; Bands VII., VIII., and IX. being especially broad and black; Band VIII. the broadest and blackest of all. They seemed as if a little further expansion would make them swallow up the whole of this portion of the spectrum. The bands were less intensely marked as the red end of the spectrum was approached; the red and yellow portions of the spectrum were faint, and perhaps the bands in those districts were less easily seen on that account. The D lines could not be identified, nor could some faint bands close to D on the more refrangible side, which had been noticed the same evening in the spectrum of β *Pegasi*, be detected in this spectrum. On the other hand, a faint band, not seen in β *Pegasi*, was observed in *Mira*, below D towards the red.

Positions of the Dark Bands in Stellar Spectra of the Third Type (Secchi's).

No. of Band, Dunér's Numeration.	α Orionis. 1876, Jan. 28.	α Orionis. 1876, Feb. 29.	α Orionis. 1887, Dec. 16.	β Pegasi. 1876, Oct. 18.	β Pegasi. 1876, Nov. 29.	ρ Persei. 1876, Oct. 18.	α Herculis. 1877, May 7.	α Herculis. 1877, June 4.	α Herculis. 1877, July 2.	α Herculis. 1883, May 2.	Mira, o Ceti 1888, Oct. 5.	Mean.
Band I.	...	6482 ±	6540 ±	...	...	...	6560 ±	...	6600 ±	...	6587 ±	6554 ±
Band II.	6198	6146	6173	6169	6168	6153	6161	...	6152	6153	6153	6163
A faint band	...	6050	...	...	...	...	...	...	...	...	...	6050
Band III.	5863	5850	5859	5869	5870	5866	...	...	5861	5865	5842	5861
A second edge to Band III.	...	...	5822	5830	...	...	5825	...	5824	...	...	5825
A faint band	5741	...	5779	5750	...	...	...	...	...	...	...	5757
Band IV.	...	5563	5577	5610	5610	5608	5608	...	5620	5592	5606	5599
Band V.	5459	5446	5445	5450	5446	5445	5445	5448	5456	5452	5448	5449
Band VI.	5251	5251	...	5272	...	...	...	...	...	...	...	5258
Band VII.	5165	5165	5164	5164	5167	5160	5169	5169	5169	5167	5171	5166
Band VIII.	4951	4951	4954	4953	4956	4950	4963	...	4956	4960	4956	4955
Band IX.	4758	4761	4780	4761	...	4752	4759	...	4771	4776	4764	4765
Band X.	...	...	4603	4595	...	4641 ±	...	...	4567	4609	...	4602
Band XI.	4446 ±	...	...	4360 ±	...	4359 ±	...	...	...	...	...	4388 ±

The above determinations of the wave-lengths of the less refrangible edges of the dark bands in stellar spectra of the third type (Secchi's) were made with micrometer B of the single-prism spectroscope, measures of the position of the D lines, as given by a sodium flame, being made on each occasion for index error. The measures of the stellar bands, after correction for index error, have been converted into wave-lengths by reference to a curve connecting micrometer readings and wave-lengths, and laid down from a series of measures of the principal lines in the solar spectrum made with the same instrument.

III. P and R Cygni.

The object of these observations was the detection and measurement of bright lines in the spectra of the two stars.

R Cygni.

R Cygni was observed on 1888, September 21 and October 1. On the former occasion bright lines were observed near D_3 and F, but, a mist rising, the star was lost before any measures could be obtained. On October 1 only the F line was seen as bright, and its position was measured once, the resulting wave-length being

Tenth-metres
4866.

The general spectrum of the star, apart from the bright line at F, appeared to be that of Secchi's fourth type—viz. one crossed by shaded dark bands, which are sharp and dark on their less refrangible side and shade off towards the violet.

P Cygni.

P Cygni was observed on 1888, October 1, and the following measures were obtained for the position of a bright line in its spectrum :—

Tenth-metres.		Tenth-metres.
4861		4860
4859		4858
4859		4852
4862		4853
4860	Mean	4858·4
4860		

The bright line, which appeared a little diffused at the edges, was observed without much difficulty. No other bright lines were detected, and, no cylindrical lens being used, no dark bands could be made out.

The single-prism spectroscope was used both for *R* and *P Cygni*, and no cylindrical lens was employed. The D lines, as given by a sodium flame, were used as a reference spectrum for index error, as in the measures given in Section II.

IV. Comets 1888 *a* and 1888 *e*.

These two comets were observed with the single-prism spectroscope, without a cylindrical lens.

Comet 1888 *a* (*Sawerthal*)

was observed on 1888, April 10, 19, and May 3. The spectrum was almost wholly continuous, but on April 19 two very feeble bright bands were detected, nearly, if not quite, coincident with the bands in the green and yellow of the spectrum of the Bunsen flame. In the case of the band in the green a direct comparison was made between the two spectra, which left no doubt of their coincidence. The third carbon band—that in the blue—was not quite satisfactorily made out, but its presence was suspected as a slight local brightening of the continuous spectrum. On May 3 no trace of the yellow and blue bands could be detected in the spectrum of the comet, and the presence of the green band was only very faintly suspected. The spectrum of the comet was practically wholly continuous. It ended rather abruptly at or near D.

The spectrum of the tail was followed to a considerable distance from the nucleus, but it differed from that of the nucleus only in its greater faintness.

Comet 1888 *e* (*Barnard* 1888, *September* 2)

was observed on 1888, November 27. The spectrum was almost wholly continuous. By carefully narrowing the slit it became possible to see that there was a local, ill-defined brightening, corresponding nearly to the green carbon band, but apparently further towards the blue. On narrowing the slit further this brightening was lost, and only the continuous spectrum was seen. This was noted only for the nucleus and its immediate neighbourhood, the fainter outlying portions of the coma not being bright enough to give a perceptible spectrum with the slit as now narrowed. On the whole, the evidence for anything beyond a purely continuous spectrum was but small; the hydrocarbon spectrum was evidently quite an unimportant and subordinate feature.

Note on the Spectrum of the Great Nebula in Orion.

By E. W. Maunder.

As I have recently been informed that an observation of mine of the brightest line in the spectrum of the Great Nebula in *Orion* has been somewhat misunderstood, it being supposed, as I am told, that I had claimed to have seen this line as distinctly a fluted band, I have thought it would be well if I explained it to the Society.

The observation in question was made on February 18, 1884, in the course of my usual work of the measurement of the displacement of the lines in stellar spectra. I was using the half-prism spectroscope in the direct position on the South-East equatorial of 12·8 inches aperture, and I had endeavoured, not very successfully, to measure the displacement of the bright F line in the spectrum of the nebula, using for the purpose a dispersion of one "half-prism." I then turned to the line of the nebular spectrum near λ 5005, and found this very much brighter than the F line. It had occurred to me, as this line in the nebular spectrum had sometimes been supposed to be due to nitrogen, the spectrum of which shows a very bright pair of lines at this place, that it would be well to ascertain if the nebular line could be divided, so I put in a second "half-prism," and examined the line at λ 5005 again. The dispersion now used was equivalent to that of sixteen flint prisms of 60°, or about 80° from A to H. The two nitrogen lines were widely separated, and though differing in wave-length only by three tenth-metres, their angular separation was 7′, or more than two revolutions of the eyepiece micrometer (one hundred revolutions to the inch). The slit was very narrow, about 0″·5 of arc, or $\frac{1}{2000}$ inch, and the spectroscope had been very carefully focussed during the day on the same part of the solar spectrum, and with the same dispersion. With this dispersion and slit the three principal lines of the nebular spectrum, viz. F, λ 5005, and the bright line between them, were seen as very narrow bright lines. But none of the three nebular lines were perfectly sharp; each showed a slight raggedness at both edges; but in the case of the line near λ 5005 it was clear that this fringe or raggedness was more developed towards the blue than towards the red. In the original record of the observation published in the Greenwich Observations for 1884, my note reads as follows:—"None of the lines in the spectrum of the nebula are, however, very sharp. λ 5005 showed a faint fringe mainly on the side nearer the blue." In the case of the two other lines, they were not bright enough for it to be possible to ascertain whether the fringes were symmetrical or not.

But λ 5005 was clearly a single line. There was no trace of any bright line or series of bright lines close to it on either side; no trace of a fluting properly so-called. The entire line, fringes and all, was only a fraction of a tenth-metre in total breadth; all that was remarked about it was:—

(1) That it was a single, not a double, line.

(2) That it was not quite sharp at either edge.

(3) That it was more shaded on the more refrangible edge than on the less refrangible.

The power of the eyepiece used was 14 on a viewing-telescope of 10·5 inches focal length.

The observation therefore does not afford any strong confirmation of Mr. Lockyer's view that this line in the spectrum of nebulæ is due to the fluting of magnesium, but at the same time it is not absolutely inconsistent with it.

Observations of the Planet Iris and Comparison Stars, made with the Meridian Circle at Dunsink. By Arthur A. Rambaut, M.A., Assistant Astronomer at Dunsink Observatory.

(*Communicated by Sir R. S. Ball.*)

Early in September 1888, we received from Dr. Gill a list of twenty-eight stars, which he proposed to use as comparison stars for a determination of the parallax of the planet *Iris*, with a request that we should determine their places with our meridian circle, and that we should at the same time procure as many meridian observations as possible of the planet.

This work was commenced at once on receipt of Dr. Gill's communication, but owing to the unfavourable state of the weather the list, to which two stars were added during the progress of the work, was not completed till January 10 of this year.

The places of the stars given below are strictly differential, both in right ascension and declination, as the clock error and the equator point of the circle were always determined by observations of a few stars selected from the *Berliner Jahrbuch*. These stars, which were chosen as being conveniently situated in regard to the time of their culmination, and because their zenith distances did not greatly differ from that of Dr. Gill's stars, are contained in the following list:—

List of Standard Stars.

No.	No. in Fund. Cat.	Name.	Mean R.A. 1888·0.	Mean Decl. 1888·0.
			h m s	o ′ ″
1	15	ϵ Piscium	0 57 7·815	+ 7 17 13·22
2	22	η Piscium	1 25 29 397	+14 46 5·08
3	25	o Piscium	1 39 28·734	+ 8 35 37·31
4	27	α Triang.	1 46 41·867	+29 1 58·17
5	30	β Arietis	1 48 27·172	+20 15 36·63
6	42	μ Ceti	2 38 53·207	+ 9 38 26·70
7	44	41 Arietis	2 43 23·480	+26 47 53·75
8	47	α Ceti	2 56 25·448	+ 3 38 59·23
9	359	δ Arietis	3 5 13·470	+19 18 8·83

The azimuth error of the instrument was on every occasion determined by observations of *Polaris* at upper culmination, in combination with the clock stars observed. The other errors of the instrument were determined, and the observations reduced, in the manner described in the Fourth and the Sixth Parts of the *Dunsink Observations and Researches*. In addition to the observations of standard stars in zenith distance, readings of the nadir point of the circle were also taken, two before and two after, each series of observations. The equator point, as determined from these nadir readings, is given in the eighth column of the *Table of Instrumental Corrections*. In obtaining this quantity the latitude of the meridian circle is taken as being $53^\circ\ 23'\ 13''{\cdot}1$, as determined from a series of observations of *Polaris* above and below the pole, made during the winter of 1887–88, an account of which will shortly be published in the *Scientific Transactions of the Royal Dublin Society*. The seventh column of the same table contains this quantity as derived from observations of standard stars, and this alone has been used in the reductions.

The numbers in the ninth column refer to the list of standard stars given above, and show what stars were observed on each night.

The symbol (α) or (δ) following any number implies that the star corresponding to this number was observed only in right ascension or declination as the case may be.

Table of Instrumental Corrections.

The values of the various quantities in this table are computed for the epoch $2^{h}\cdot0$ Sidereal Time.

Date. 1888.	Clamp.	Incl. s	Azim. s	Collim. s	$\Delta t + b \sec\phi$. s	Equator Point (S.) ° ′ ″	(N.) ″	Standard Stars.
Sept. 5	W	+0·202	−0·206	−0·048	−197·28	171 36 37·59	37·56	1, 2, 6, 7
7		+0·200	−0·246	−0·046	−200·93	38·09	38·10	1, 2, 6, 8
12		+0·163	−0·291	−0·052	− 29·28	36 81	36·85	1 (δ), 2, 4, 7, 8 (α)
16		+0·166	−0·143	−0·016	− 35·76	36·49	36·52	1, 2, 7, 8
26		+0·180	−0·082	+0·003	− 53·09	36·54	36·71†	1, 2
Oct. 1		+0·202	−0·156	[0·000]	− 62·19	39·22	††	2, 4, 7, 8
3		+0·138	−0·100	+0·003	− 65·22	38·83	††	1 (α), 2, 3, 6
4		+0·139	−0·055	+0·019	− 66·70	40·16	40·59	1 (α), 2 (δ), 3, 7, 8
13	E	+0·086	−0·098	−0·144	− 74·92	171 37 26·73	26·62	1, 2, 6, 7
14		+0·061	−0·153	−0·180	− 75·68	26·75	26·35	1, 2, 6, 7
20		+0·067	−0·069	−0·136	− 80·47	24·94	24·97	1, 2, 5, 6, 7
22		+0·089	−0·014	−0·125	− 82·17	26·10	25·98	1, 2, 6, 7
30		+0·182	−0·198	−0·188	− 92·09	27·71	27·47	1, 2, 6, 7
Nov. 16		+0·092	−0·230	−0·166	−118·90	25·86	25·97†	1, 2
20		+0·123	−0·266	−0·169	−124·42	27·24	27·42	2, 3, 6, 7
25		+0·112	−0·132	−0·018*	−130·17	25·34	25·03	1, 2, 6, 7
27		+0 136	−0·094	+0·008	133·30	26·67	25·97	1, 2, 6, 7

Date.	Clamp.	Incl.	Azim.	Collim.	$\Delta t + b \sec \phi$.	Equator Point (S.)	(N.)	Standard Stars.
1888.		s	s	s	s	° ′ ″	″	
Nov. 30		+0·091	[−0·162]	−0·024	− 17·58	171 37 26·11	††	5, 6, 7
Dec. 3		+0·049	−0·231	−0·051	− 21·04	23·51	22·78	2, 5. 6 (δ), 7
8		+0·114	−0·186	−0·019	− 26·43	26·17	25·68	1, 2, 6, 7
9		+0·109	−0·181	−0·017	− 27·54	26·32	26·15	1, 2, 6, 7
11	W	+0·040	[−0·211]**	+0·077	− 29·90	171 36 38·16	38 04†	6, 7, 8, 9
16		+0·040	−0·161	+0·028	− 35·21	38·77	38·55	2, 3. 6, 9
20		−0·016	−0·146	+0·083	− 40·07	36·71	37 26	2, 3, 6, 7
24		+0·015	−0·121	+0·064	− 45·33	37·38	37·20	2, 3, 6, 7
26		+0·016	−0·286	+0·004	− 47·83	38·49	38·23	2, 3, 6, 7
27		−0·007	−0·210	+0·025	− 49·26	38·25	37·62	2, 3, 6, 7
28	E	+0·010	−0·276	−0·002	− 50·58	171 37 24·39	23·52	2, 3, 6, 7
29		+0·038	−0·220	+0 026	− 51·86	24·27	23·79	2, 3, 6, 7
30		+0·023	−0·191	+0·011	− 53·03	25·45	24·95	2, 3, 6, 7
1889.								
Jan. 3		−0·052	−0·195	+0·033	− 57·17	24·81	23·76	2, 3, 6, 7
5	W	−0·105	−0·270	+0·026	− 59·07	171 36 37·76	37·08	2, 3, 6, 7
10	W	−0·083	−0·260	+0·044	− 63·96	37·68	36·45	2, 3, 6, 9

* Spider lines cleaned on November 24.
** Determined on December 10.

† Only two determinations of nadir.
†† Nadir not observed.

Probable Error of the Resulting Places.

I have computed the probable error of a single observation of right ascension from the whole series of results, and I find that for a star of declination +20° 30′ (the mean declination of Dr. Gill's list) it is

$$\pm 0^{s}\cdot 032,$$

which corresponds to a probable error of $\pm 0^{s}\cdot 030$ at the equator.

In declination the probable error of a single observation as computed from the whole series is

$$\pm 0''\cdot 405.$$

Separate Results.

No.	D.M.	Date. 1888.	Clamp.	R.A. 1880·0. h m s	Decl. 1880·0. ° ′ ″	Remarks.
1	+17°, 307	Sept. 5	W	1 57 34·09	+17 42 52·7	
		7	W	33·99	53·8	
		Oct. 13	E	33·91	51·9	
		14	E	33·97	52·1	
		Dec. 24	W	33·95	52·3	
		27	W	33·98	52·3	
		29	E	33·95	51·7	
				1 57 33·960	+17 42 52·40	
2	+19°, 324	Sept. 12	W	2 0 4·00	+20 3 26·8	
		16	W	3·91	25·8	
		Oct. 20	E	3·88	25·9	
		22	E	3·97	26·0	
		Dec. 26	W	3·92	25·9	
		28	E	3·91	25·2	
				2 0 3·932	+20 3 25·93	
3	+17°, 315	Sept. 26	W	2 1 36·99	+17 29 43·8	See note (*a*).
		Oct. 1	W	37·06	43·8	Very unsteady.
		30	E	37·04	44·1	
		Nov. 16	E	37·03	[45·2]	See note (*b*).
		Dec. 30	E	36·99	43·8	
		1889. Jan. 10	W	37·09	43·0	Through clouds
				2 1 37·033	+17 29 43·70	

No.	D.M.	Date. 1888.	Clamp.	R.A. 1880·0. h m s	Decl. 1880·0. ° ′ ″	Remarks.
4	+16°, 247	Oct. 3	W	2 3 14·05	+16 41 56·9	See note (*c*).
		4	W	13·78	54·7	
		13	E	13·93	55·1	
		14	E	13·81	54·3	Rather unsteady.
				2 3 13·892	+16 41 55·25	
5	+19°, 329	Sept. 5	W	2 3 29·90	+19 49 2·4	
		7	W	29·95	4·2	
		Dec. 16	W	29·85	2·4	
		29	E	29·87	1·4	
				2 3 29·892	+19 49 2·60	
6	+18°, 277	Nov. 20	E	2 4 25·07	+18 58 —	
		Dec. 20	W	25·07	18·1	Dark field.
		24	W	25·03	18·0	Dark field.
		28	E	25·08	18·1	
		1889. Jan. 3	E	25·05	18·0	
				2 4 25·060	+18 58 18·05	
7	+20°, 341	1888. Oct. 22	E	2 5 6·09	+20 50 57·2	
		Dec. 26	W	6·08	57·6	
		27	W	6·04	56·9	
		30	E	5·95	56·0	
				2 5 6·040	+20 50 56·92	
8	+21°, 298	Nov. 27	E	2 6 2·89	+21 27 25·7	
		30	E	2·94	24·9	
		Dec. 11	W	2·89	26·4	
		1889. Jan. 5	W	2·88	26·7	
				2 6 2·900	+21 27 25·92	
9	+20°, 348	1888. Sept. 16	W	2 6 31·90	+20 41 5·0	
		26	W	—	5·5	
		Oct. 20	E	31·78	3·7	
		30	E	31·84	3·0	
		1889. Jan. 10	W	31·90	3·4	
				2 6 31·855	+20 41 4·12	

No.	D.M.	Date. 1888.	Clamp.	R.A. 1880·0. h m s	Decl. 1880·0. ° ′ ″	Remarks.
10	+18°, 283	Sept. 12	W	2 7 38·96	+19 5 23·2	
		Oct. 1	W	38·91	23·0	
		Nov. 25	E	38·89	22·3	
		Dec. 9	E	38·78	21·9	
				2 7 38·885	+19 5 22·60	
11	+21°, 304	Sept. 5	W	2 8 39·57	+22 6 26·0	
		7	W	39·71	25·8	
		Dec. 3	E	39·61	25·6	
		8	E	39·67	26·1	Set hurriedly.
		28	E	39·64	26·0	A ✱ 8·5 mag. s.p.
		29	E	39·58	26·1	
				2 8 39·630	+22 6 25·93	
12	+21°, 317	Oct. 3	W	2 11 26·21	+22 8 33·2	See note (*d*).
		4	W	26·10	35·1	
		13	E	26·14	36·1	
		14	E	26·12	34·7	
				2 11 26·133	+22 8 34 77	
13	+19°, 340	Nov. 20	E	2 11 53 63	+19 22 57·2	Through clouds.
		30	E	53·72	56·4	
		Dec. 11	W	53·67	57·1	
		16	W	53·62	57·0	
		30	E	53·63	56·5	
				2 11 53·654	+19 22 56·84	
14	+21°, 321	Oct. 22	E	2 12 16·91	+21 22 49·4	See note (*e*).
		30	E	16·90	49·7	
		Dec. 20	W	16·77	49·4	Dark field.
		24	W	16·88	49·8	
				2 12 16·865	+21 22 49·57	
15	+22°, 329	Sept. 16	W	2 12 38·52	+22 39 3·5	
		Oct. 1	W	38·42	4·4	
		20	E	38·46	2·6	
		Dec. 9	E	38·37	2·0	
		1889. Jan. 10	W	38·50	2·3	
				2 12 38·452	+22 39 2·96	

No.	D.M.	Date. 1888.	Clamp.	R.A. 1880·0. h m s	Decl. 1880·0. ° ′ ″	Remarks.
16	+19°, 346	Sept. 7	W	2 14 17·86	+19 36 36·9	See note (*f*).
		12	W	17·97	36·2	
		Dec. 3	E	18·01	36·0	Dark field.
		Dec. 26	W	17·95	34·8	See note (*g*).
		1889. Jan. 3	E	17·95	35·5	Dark field.
				2 14 17·948	+19 36 35·88	
17	+22°, 331	1888. Nov. 27	E	2 14 53·79	+22 54 47·6	
		Dec. 8	E	53·96	47·6	
		11	W	53·93	47·2	
		16	W	53·93	47·7	
				2 14 53·902	+22 54 47·52	
18	+20°, 388	Sept. 5	W	2 17 29·95	+20 54 16·6	
		16	W	[30·18]	17·6	See note (*h*).
		Oct. 13	E	29·99	17·5	
		14	E	29·93	17·7	
		Dec. 24	W	29·90	16·9	Dark field.
				2 17 29·943	+20 54 17·26	
19	+24°, 347	Sept. 26	W	2 19 27·20	+24 39 10·7	See note (*i*).
		Oct. 1	W	27·35	12·8	See note (*j*).
		20	E	27·36	10·9	
		Nov. 20	E	27·37	10·4	
				2 19 27·320	+24 39 11·20	
20	+22°, 347	Sept. 7	W	2 20 38·07	+22 22 28·1	
		12	W	37·93	26·9	
		Nov. 25	E	37·93	27·2	
		Dec. 3	E	38·09	27·4	See note (*k*).
		1889. Jan. 10	W	38·01	27·3	See note (*l*).
				2 20 38·006	+22 22 27·38	
21	+23°, 326	1888. Nov. 27	E	2 21 53·25	+24 7 45·1	See note (*m*).
		Dec. 9	E	53·24	45·5	
		11	W	53·27	43·0	
		16	W	53·28	44·6	
				2 21 53·260	+24 7 44·55	

No.	D.M.	Date. 1888.	Clamp.	R.A. 1880·0. h m s	Decl. 1880·0. ° ′ ″	Remarks.
22	+22°, 345	Oct. 3	W	2 22 50·60	+22 58 6·4	Dark field.
		4	W	50·59	6·9	Good.
		13	E	50·55	6·8	Dark field.
		14	E	50·49	6·5	
		1889. Jan. 5	W	50·60	5·8	
				2 22 50·566	+22 58 6·48	
23	+20°, 404	1888. Sept. 16	W	2 22 57·67	+21 5 39·1	
		Nov. 30	E	57·73	38·2	
		Dec. 26	W	57·67	37·7	
		27	W	57·64	37·3	
		28	E	57·72	38·4	See note (*n*).
				2 22 57·686	+21 5 38·14	
24	+24°, 358	Sept. 5	W	2 24 5·78	+24 44 17·4	
		Oct. 30	E	5·78	18·3	
		Dec. 20	W	5·75	17·3	Dark field.
		24	W	5·76	17·1	
		29	E	5·80	17·6	
		30	E	5·78	17·9	
				2 24 5·775	+24 44 17·60	
25	+21°, 349	Sept. 12	W	2 26 1·67	+21 50 17·5	
		Oct. 1	W	1·65	17·4	
		Nov. 20	E	1·66	17·3	Through clouds.
		25	E	1·71	17·3	
				2 26 1·672	+21 50 17·37	
26	+24°, 369	Sept. 16	W	2 28 11·90	+24 24 4·1	
		26	W	11·76	2·5	See note (*o*).
		Dec. 3	E	11·92	3·4	See note (*p*).
		9	E	11·78	4·0	
				2 28 11·840	+24 24 3·50	
27	+22°, 368	Oct. 4	W	2 28 16·64	+22 28 35·1	
		Nov. 27	E	16·59	35·2	
		Dec. 8	E	16·65	35·4	
		11	W	16·59	34·2	
				2 28 16·617	+22 28 34·97	

No.	D.M.	Date. 1888.	Clamp.	R.A. 1880·0. h m s	Decl. 1880·0. ° ′ ″	Remarks.
28	+22°, 372	Sept. 5	W	2 30 18·60	+22 33 49·4	
		Oct. 30	E	18·71	50·4	
		Nov. 30	E	18·70	49·5	
		Dec. 24	W	18·68	49·1	
		29	E	18·64	48·8	
		1889. Jan. 5	W	18·70	49·3	
				2 30 18·672	+22 33 49·42	
29	+24°, 376	1888. Oct. 20	E	2 30 32·90	+24 9 33·3	D.M. +24°,375 p., $3'' \pm n$.
		22	E	33·01	33·6	Oct. 20 $\Delta\alpha = 2^s{\cdot}85$
		Dec. 16	W	32·95	32·9	,, 22 $\Delta\alpha = 3^s{\cdot}07$
		20	W	32·98	33·1	Dec. 30 $\Delta\alpha = 2^s{\cdot}78$
		3	E	32·97	33·3	$\Delta\alpha = 2^s{\cdot}90$
				2 30 32·962	+24 9 33·24	
30	+22°, 375	Nov. 20	E	2 31 25·30	+22 38 34·0	
		25	E	25·34	34·0	
		Dec. 26	W	25·32	33·7	Rather unsteady.
		27	W	25·31	33·0	
		28	E	25·32	33·9	Dark field.
				2 31 25·318	+22 38 33·72	

Notes.

(*a*) Through thin clouds.

(*b*) Microscopes V. and VI. were read immediately. Then the telescope was set for *Iris*, after which the telescope was re-set by the first two readings, and those of VII. and VIII. taken.

(*c*) Dark field. Faint through clouds.

(*d*) Dark field. Observed across only five wires. Half weight in R.A.

(*e*) Through clouds. Appears brighter than 8^m.

(*f*) A 9^m star f. $6^s{\cdot}5$, $2' \pm$ s. (*g*) Rather faint for bright field.

(*h*) R.A. very bad. Appears less than $8^m{\cdot}5$. Reject.

(*i*) Through clouds. Faint. Dark field.

(*j*) Through clouds, drifting swiftly by. (*k*) Very faint through clouds.

(*l*) Faint through clouds. Decl. appeared good as seen once or twice through clear breaks.

(*m*) A star, R.A. $2^h\ 19^m\ 25^s{\cdot}60$, Decl. + 24° 10′ 5″·3, observed on December 8, 1888, by mistake for this.

(*n*) Faint through clouds. Dark field.

(*o*) Through clouds. Dark field.

(*p*) Very faint through clouds. Dark field.

Observations of the Planet Iris.

[The places given in this list are not corrected for annual aberration or parallax.]

Date. 1888.	App. R.A. h m s.	App. Decl. ° ′ ″	Remarks.
Sept. 7	2 29 47·89	+23 27 50·9	Ill-defined.
12	32 34·65	+23 49 55·2	Appears slightly reddish. A ✶ 8^m (D.M. +23°, 349) *f.* $13^s·5$, 20″ ± *n*.
16	34 12·35	+24 3 53·4	
26	35 47·89	+24 22 46·2	Through clouds. Only five wires.
Oct. 1	35 13·05	+24 22 41·9	Ill-defined.
3	34 43·99		Only two wires. Appeared for only a few secs. through clouds.
4	34 26·21	+24 19 18·5	
13	30 18·64	+23 53 30·9	Very well seen. Blue rather than red.
14	29 42·50	+23 49 11·3	
20	25 37·76	+23 17 33·7	
22	24 7·72	+23 4 54·5	Definition good.
30	17 45·70	+22 5 20·8	
Nov. 16	5 52·90		Only three wires. Scarcely visible.
20	4 4·09	+18 58 49·8	D.M. +18°, 277, *f.* $24^s·11$, 17″ ± *s*.
25	2 32·47	+18 18 3·6	
27	2 10·34	+18 2 53·0	
30	1 53·65	+17 51 31·3	
Dec. 8	2 47·36	+16 54 8·1	
9	3 3·94	+16 49 14·0	D.M. +16°, 247, *f.* 11^s ± , 7′ ± *s*. in same field.
11	3 44·19	+16 40 10·1	Only two microscopes (V. and VI.) read at once. I afterwards reset by means of these, and read VII. and VIII.
26	13 5·74	+16 1 59·7	Only five wires. Only one microscope (V.) read until after the transit of 41 *Arietis*.
27	13 58·25	+16 1 12·8	
28	14 52·66	+16 0 38·0	A $9^m·5$ ✶ *p*. $2^s·5$, 1′ ± *n*. not in D.M.
29	15 48·54	+16 0 14·3	
30	16 46·29	+16 0 2·5	Appeared about $8^m·5$ through a slight haze.
1889. Jan. 10	2 29 5·59	+16 9 45·1	Another star of same mag. (D.M. +15°, 354) $26^s·75$ *f.* from 2′ to 3′ south.

On December 3 the star D.M. +17°,315 was observed by mistake for *Iris*. The resulting place is R.A. 2^h 1^m $37^s·03$, Decl. +17° 29′ 43″·4.

Mean Places of Comparison Stars for Heliometer Observations of Iris.

No.	Mag.	Mean R.A. 1888·0.	Ann. Prec.	Sec. Var.	No. of Obs.	Mean. Decl. 1888·0.	Ann. Prec.	Sec. Var.	References.
		h m s	s	s		° ′ ″	″	″	
1	7·0	1 57 33·960	+3·28207	+0·01681	7	+17 42 52·40	+17·4720	−0·2425	Arm. 454, P. 243, T. 673, W. 1331, 7 yr. 136, 9 yr. 192.
2	7·7	2 0 3·932	·31666	·01837	6	20 3 25·93	17·3637	·2494	W. 1397.
3	7·3	2 1 37·033	·28576	·01673	6, 5	17 29 43·70	17·2953	·2499	Gl. 465, P. 257, W. 1436.
4	6 8	2 3 13·892	·27789	·01626	4	16 41 55·25	17·2234	·2521	W. 1482.
5	7·5	2 3 29·892	·31972	·01824	4	19 49 2·60	17·2114	·2558	W. 1.
6	6·0	2 4 25·060	·30991	·01770	5, 4	18 58 18·05	17·1699	·2567	Arm. 473, B. 296, B.A.C. 669, P. 267, T. 702, W. 19, Y. 977, 7 yr. 139, 9 yr. 198.
7	7·5	2 5 6·040	·33681	·01894	4	20 50 56 92	17·1391	·2600	Gl. 479, P. 1, R C_2 265, W. 43.
8	8·5	2 6 2·900	·34713	·01937	4	21 27 25·92	17·0959	·2625	W. 75.
9	5·5	2 6 31·855	·33722	·01884	4, 5	20 41 4·12	17·0737	·2625	Arm. 482, B. 303, P. 11, R C_2 272, T. 718, W. 87, Y. 996, 12 yr. 193, 7 yr. 141.
10	7·2	2 7 38·885	·31706	·01780	4	19 5 22·60	17·0223	·2629	Arm. 486, T. 728, W. 130.
11	7·8	2 8 39·630	·36159	·01982	6	22 6 25·93	16·9753	·2684	
12	8·3	2 11 26·133	·36766	·01986	4	22 8 34·77	16·8449	·2735	W. 233.
13	6·0	2 11 53·654	·32847	·01801	5	19 22 56·84	16·8230	·2713	Arm. 502, Arm.$_2$ 296, B. 320, P. 49, Pond (1830) 72, R C_2 282, Y. 1029. 9 yr. 210, 12 yr. 204, 7 yr. 148.
14	8·0	2 12 16·865	·35809	·01934	4	21 22 49·57	16·8046	·2744	W. 241.

No.	Mag.	Mean R.A. 1888·0. h m s	Ann. Prec. s	Sec. Var. s	No. of Obs.	Mean Decl. 1888·0. ° ′ ″	Ann. Prec. ″	Sec. Var. ″	References.
15	6·0	2 12 38·452	+3·37764	+0·02022	5	+22 39 2·96	+16·7874	−0·2765	Arm. 297.
16	8·5	2 14 17·948	·33590	·01816	5	19 36 35·88	16·7077	·2762	
17	7·8	2 14 53·902	·38623	·02040	4	22 54 47·52	16·6786	·2813	
18	8·5	2 17 29·943	·36079	·01901	4, 5	20 54 17·26	16·5512	·2837	W. 368.
19	7·3	2 19 27·320	·42322	·02166	4	24 39 11·20	16·4539	·2924	
20	7·8	2 20 38·006	·38938	·02000	5	22 22 27·38	16·3947	·2916	W. 444, Y. 1081.
21	8·6	2 21 53·260	·42000	·02124	4	24 7 44·55	16·3313	·2965	
22	6·0	2 22 50·566	·40321	·02041	5	22 58 6·48	16·2826	·2966	Arm.$_2$ 319, R. 631, R.$_2$ 1267.
23	7·5	2 22 57·686	·37371	·01911	5	21 5 38·14	16·2766	·2945	W. 503.
24	6·2	2 24 5·775	·43476	·02167	6	24 44 17·60	16·2184	·3016	Arm. 544, W. 525, Y. 1101.
25	8·0	2 26 1·672	·39122	·01960	4	21 50 17·37	16·1184	·3011	W. 587, Y. 1122.
26	8·2	2 28 11·840	·43788	·02136	4	24 24 3·50	16·0048	·3090	W. 635.
27	8·1	2 28 16·617	·40589	·02001	4	22 28 34·97	16·0006	·3063	W. 637.
28	7·6	2 30 18·672	·41125	·02004	6	22 33 49·42	15·8926	·3102	W. 688.
29	7·0	2 30 32·962	·43869	·02117	5	24 9 33·24	15·8799	·3130	Arm. 565, Arm.$_2$ 338, B. 361, P. 128, R C_2 314, T. 867, W. 693, Y. 1150, 12 yr. 224.
30	8·3	2 31 25·318	+3·41471	+0·02007	5	+22 38 33·72	+15·8331	−0·3123	W. 710.

The abbreviations in the last column are the same as those used in the second Armagh Catalogue, which is here denoted by Arm.$_2$.

Dunsink : 1889, *February* 26.

Observations of the Variable Star S (10) Sagittæ.
By J. E. Gore.

The following are my observations of this short period variable during the year 1888. They form a continuation of the observations given in *Monthly Notices* for March 1888.

The comparison stars are as before.

	Mag.
11 Sagittæ	5·8
DM. + 16°, 4086	7·0

Date.	Dublin M.T. h m	Mag.	Date.	Dublin M.T. h m	Mag.
1888, Jan. 2	6 22	6·25	1888, Oct. 22	10 10	6·5
5	5 45	5·65	Nov. 6	7 55	6·16
8	6 10	5·7	9	7 37	6·16
Oct. 5	10 15	6·25	13	7 30	5·85
10	10 40	5·7	14	6 45	6·16
12	10 15	6·0	25	6 48	6·28
13	7 35	6·16	27	8 55	5·7
13	10 42	6·25	30	6 44	5·9
14	6 58	6·28	Dec. 7	7 34	5·8
16	10 15	5·7	8	8 2	5·8
20	9 25	6·25	9	6 36	5·9
22	7 52	6·4	26	6 40	5·9

Note on a Red Star. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

Whilst searching for Faye's Comet on the night of 1888, November 27, which could not be seen with the 10-inch Barclay equatorial, a star was noticed by Mr. Bellamy as "a vividly red coloured star."

On February 9, 1889, Mr. Robinson looked for the above star, and made the following observations: "This star was easily picked up from its colour contrasting with all the other stars in the vicinity. It is undoubtedly red. A white star, slightly fainter, precedes 4′ N.; also a bright white star follows 6′ S. The star turns out to be Lalande 16320, and the following are the positions of the star and those compared with it on 1889, February 9.

	Approx. R.A. 1889·0. h m s	Approx. N.P.D. ° ′ ″	Colour.	Observed Magnitude.
Lamont 22	8 13 31	86 49 19	White	8·75
Lalande 16320	8 14 18	86 53 13	Red	8·5
Lalande 16341	8 14 54	86 59 4	White	7·0

Radcliffe Observatory, Oxford:
1889, *March* 7.

Observations of Comet Barnard (1888, *September* 2) *and Comet Barnard* (1888, *October* 30), *made at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, M.A., F.R.S., Radcliffe Observer.*)

The following observations were made with the Barclay equatorial, using the ring-micrometer, with power 100.

Comet Barnard (1888, *September* 2).

Date.	G.M.T.	Local Sidereal Time.	Observer.	✱−✱ (Corrected for Refraction only.) R.A.	✱−✱ (Corrected for Refraction only.) N.P.D.	No. of Comparisons.	Apparent R.A. of Comet.	Parallax in R.A. / p	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. / q	Log $(q \times \Delta)$.	Reference to Comparison Star.
1888.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Nov. 26	8 56 30	1 16 18	F. B.	−0 32·68	+1 35·0	6	2 49 14·51	−0·13	9·1598	95 11 22·4	−6·66	0·8653	(*a*)
26	8 56 39	1 16 27	F. B.	−3 10·50	+1 4·6	7	2 49 13·94	−0·13	9·1598	95 11 15·7	−6·66	0·8653	(*b*)
26	9 7 40	1 27 30	F. B.	−0 35·87	+1 39·4	8	2 49 11·32	−0·12	9·1067	95 11 26·8	−6·67	0·8658	(*a*)
27	9 52 5	2 15 59	W.	−0 36·05	+6 12·2	12	2 42 12·64	−0·04	8·6210	95 26 54·8	−6·67	0·8686	(*c*)
27	10 17 59	2 41 57	W.	−0 42·78	+6 23·7	3	2 42 5·91	0·00	...	95 27 6·3	−6·68	0·8688	(*c*)
27	10 17 59	2 41 57	W.	−2 43·50	+0 13·8	3	2 42 5·82	0·00	...	95 27 8·0	−6·68	0·8688	(*d*)
27	13 24 3	5 48 32	F. B.	+0 46·16	...	7	2 41 12·88	+0·24	9·4274	...	...	...	(*e*)
27	13 24 3	5 48 32	F. B.	−1 37·17	+5 45·7	7	2 41 12·71	+0·24	9·4274	95 28 48·7	−6·53	0·8592	(*f*)
Dec. 22	9 13 2	3 15 23	R.	−0 28·34	−6 14·7	7	0 41 37·67	+0·15	9·3599	97 39	−4·86	0·8701	(*g*)
1889.													
Feb. 9	6 50 48	4 5 57	R.	+0 47·79	...	5	23 42 28·69	+0·13	9·5259	...	...	...	(*h*)
9	6 53 0	4 8 9	R.	...	−2 17·4	4	...	...	...	94 29 3·9	−2·75	0·8485	(*h*)

Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1888·0.	Reduction to Apparent R.A.	Mean N.P.D. 1888·0.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	2 49 44·27	+2·92	95 9 55·8	− 8·4	W. B. II. 838.
(*b*)	2 52 21·52	+2·92	95 10 19·3	− 8·3	W. B. II. 887.
(*c*)	2 42 45·80	+2·89	95 20 51·1	− 8·5	Pola Meridian Obs. *Ast. Nach.* No. 2819.
(*d*)	2 44 46·42	+2·90	95 27 2·6	− 8·4	Mean of Karlsruhe (1885) and Radcliffe (1883).
(*e*)	2 40 23·83	+2·89	95 25 43·7	− 8·6	Mean of Karlsruhe (1885) and Radcliffe (1886).
(*f*)	2 42 46·98	+2·90	95 23 11·5	− 8·5	Mean of W. B. II. 708 and Schjellerup 785.
(*g*)	0 42 3·82	+2·19	97 46	− 9·3	Schön. Z. −7°, No. 124.
	Mean R.A. 1889·0.		Mean N.P.D. 1889·0.		
(*h*)	23 41 41·54	−1·64	94 31 10·4	+10·9	Mean of Schön. Z. −4°, 5955 and 1 equatorial comparison with W. B. XXIII. 1041.

Observers' Remarks.

1888, Nov. 26.—Nucleus 10–9 mag.

Nov. 27, 13^h.—Nucleus fainter than on Nov. 26, being now about 10½ mag.

Nov. 27.—Distinct planetary nucleus about 10 mag.

Dec. 22.—Nucleus mag. 10.

1889, Feb. 9.—Comet very faint, only just discernible. Like a small circular nebula with central condensation. Comet low.

In the computations of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, Δ, have been taken from the *Astronomische Nachrichten*, Nos. 2867 and 2868.

Observations of Comet Barnard (1888, *September* 2) **with the Transit-circle.**

1888.	G.M.T. of Transit.	Observer.	Apparent R.A. of Comet.	Apparent N.P.D. of Comet.	Parallax $\frac{\text{N.P.D.}}{q}$	Log $(q \times \Delta)$.	Observer's Remarks.
	h m s		h m s	° ′ ″	″		
Nov. 16	12 16 39	F. B.	3 57 34·18	92 9 20·8	−6·43	0·8515	Faint; difficult observation.
20	11 33 35	F. B.	3 30 9·59	93 28 39·1	−6·62	0·8587	Nucleus 10–11. Difficult but satisfactory observation.
22	11 11 51	F. B.	3 16 15·32	94 5 39·8	−6·71	0·8620	Thin clouds passing. Difficult.
27	10 18 8	F. B.	2 42 5·62	95 27 8·2	−6·67	0·8688	Not a satisfactory observation; comet very faint.

In the computation of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, Δ, have been taken from the *Astronomische Nachrichten*, Nos. 2861 and 2867.

Comet Barnard (1888, *October* 30).

The following observations were made with the Barclay equatorial, using the ring-micrometer, with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	♂ − ✶ (Corrected for Refraction only.) R.A.	♂ − ✶ (Corrected for Refraction only.) N.P.D.	No. of Comparisons.	Apparent R.A. of Comet.	Parallax in R.A. $\frac{\text{R.A.}}{p}$	Log $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. $\frac{\text{N.P.D.}}{q}$	Log $(q \times \Delta)$.	Reference to Comparison Star.
1888.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Nov. 27	15 11 14	7 36 0	F. B.	−1 11·76	...	8	10 16 58·38	−0·15	9·3792	99 51	−4·70	0·8761	(*a*)
27	15 11 14	7 36 0	F. B.	−1 43·92	+1 0·7	8	10 16 57·42	−0·15	9·3792	99 51	−4·70	0·8761	(*b*)
1889.													
Jan. 29	11 28 6	8 0 39	F. B.	+1 46·08	+7 3·7	9	10 5 49·91	−0·14	9·3013	71 22 38·2	−3·52	0·7029	(*c*)
29	12 10 52	8 43 32	F. B.	−1 17·69	+4 55·6	9	10 5 47·79	−0·09	9·1312	71 21 44·9	−3·42	0·6905	(*d*)
Feb. 1	12 39 23	9 23 57	W.	+0 53·49	+4 39·1	9	10 2 27·93	−0·05	8·8127	69 44 3·6	−3·17	0·6634	(*e*)

Assumed Places of Comparison Stars.

Comp. Star.	Mean R.A. 1888·0.	Reduction to Apparent R.A.	Mean N.P.D. 1888·0.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′	″	
(*a*)	10 18 8·31	+1·83	99 52	+5·4	Schön. Z.−9°, No. 3059.
(*b*)	10 18 39·51	+1·83	99 49	+5·4	Schön. Z.−9°, No. 3063.
	Mean R.A. 1889·0.		Mean N.P.D. 1889·0.		
	h m s		° ′ ″		
(*c*)	10 4 3·33	+0·50	71 15 29·2	+5·2	Bonn Meridian Observations, vol. vi.
(*d*)	10 7 4·99	+0·49	71 16 44·1	+5·2	Bonn Meridian Observations, vol. vi.
(*e*)	10 1 33·88	+0·56	69 39 19·2	+5·4	Radcliffe Transit-circle Observation, 1889, Feb. 4.

Observers' Remarks.

1888, Nov. 27.—A faint nebulous, almost circular, patch, about $1\frac{1}{4}'$ in diameter. Nucleus only seen at times, and is of the $11\frac{1}{2}$ mag. Observations difficult; moonlight and haze.

1889, Jan. 29.—Nucleus stellar but slightly elongated, mag. $11\frac{1}{2}$ or 12. Surrounded by a moderately bright nebulosity about 4′ in diameter. No tail.

Feb. 1.—The comet is a hazy patch of about 1′ diameter with a stellar nucleus, mag. 13.

In the computations of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, △, have been taken from the *Astronomische Nachrichten*, Nos. 2867 and 2871.

Observers: W.—Mr. W. Wickham; R.—Mr. W. H. Robinson; F. B.—Mr. F. A. Bellamy.

N.B.—The N.P.D. of the Comparison Star (*a*), *Monthly Notices*, vol. xlix. No. 2, page 84, is 7″·5 too small, and the N.P.D. of Comet Barnard (1888, Sept. 2) observed on Oct. 5 requires, therefore, to be increased by 7″·5.

Radcliffe Observatory, Oxford:
1889, *March* 7.

Discovery of Comet Brooks, a 1889. By William R. Brooks.

While sweeping the eastern heavens in the neighbourhood of the Sun, on the morning of January 15, 1889, at $6^h\ 5^m$ L.M.T., I discovered a new comet in approximately R.A. $18^h\ 04^m$; declination south 21° 20′. I had only time to take the circle readings for position—the instrument used being the new $10\frac{1}{8}$ inch equatorial of this observatory, with a large achromatic positive eyepiece giving a power of 40 diameters, and a field of 1° 20′. The nearly full Moon was just setting, and the dawn approaching, so I had but a short time in which to do my work; but fortunately the comet was in a well-marked field of telescopic stars, and so I was enabled to detect motion in a few minutes, which was rapid in a westerly course.

In the annexed diagram I show the stars used to detect motion, by alineation, my usual custom. The comet was nearly round, with slight central condensation. It was "faintish," yet brighter than well-known nebulæ in that region which were not seen. I was *sure* of its cometary nature, as I am now, and also of *motion*, which was unmistakable. Immediate telegraphic announcement was made of the discovery.

Clouds prevented another observation of the comet until the morning of the 20th, when careful sweeps were made in the direction of motion from the place of discovery, but the search was unsuccessful, owing to the bright moonlight—the Moon being only three days past the full. No other opportunity has since offered at this observatory to re-observe the comet. It must now be a long distance west of its position at the time of discovery and probably fainter, for I must have caught the object just as it was sweeping upwards from the Sun. Yet it is hoped that the comet may not be beyond telescopic reach when the present Moon is out of the way.

Smith Observatory, Geneva, N.Y., U.S.A.:
1889, *January* 25.

Observations of Comet f 1888 (*Barnard*), *made at Stonyhurst College Observatory.* By W. J. Crofton, S.J., B.A.

(*Communicated by the Rev. S. J. Perry.*)

1889.	G.M.T.	★−☄ R.A.	★−☄ N.P.D.	Apparent place of ☄ R.A.	Apparent place of ☄ N.P.D.	No. of Comps.	Comp. Star.
	h m s	s	′ ″	h m s	° ′ ″		
Jan. 22	11 3 57	−31·52	+12 33·4	10 13 0·75	75 18 13·2	3	(*a*)
Feb. 4	9 55 46	−19·2	− 4 5·5	9 59 11·4	68 12 48	4	(*b*)

Comparison Stars.

Comp. Star.	Mean R.A. 1889·0.	Reduction to date	Mean N.P.D. 1889·0.	Reduction to date.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	10 12 28·89	+0·34	75 30 41·8	+4·8	W.B.X. 170, Berl. Acad. Zon. X. Lal. 19990.
(*b*)	9 58 51·6	+0·61	68 8 37	+5·5	D.M. +22°, 2172.

Observers: W. J. Crofton and W. Carlisle.

The observations were taken over two bars at right angles and inclined at 45° to the declination circle. The corrections for refraction and parallax have been applied.

On January 22 the comet was faint and diffuse, without any clearly marked nucleus. The observation of February 4 is somewhat uncertain.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the year 1888. By John Tebbutt.

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Mar. 27	I.	Ecl. D.	Began to fade	$4\frac{1}{2}$-inch	90	23 36 40	23 37 21
27	I.	,,	Last seen	,,	,,	23 37 58	
April 2	I.	,,	Began to fade	8-inch	95	7 2 16	7 2 30
2	I.	,,	Last seen	,,	,,	7 3 26	
9	II.	Tr. Egr.	Ext. contact	,,	130	0 47 7	0 46
14	III.	Ecl. D.	Began to fade	,,	,,	23 30 19	23 33 22
14	III.	,,	Last seen	,,	,,	23 39 18	
15	III.	Ecl. R.	First seen	,,	,,	1 5 50	1 9 58
15	III.	,,	Full brightness	,,	,,	1 17 21	
19	I.	Ecl. D.	Began to fade	,,	140	23 44 13	23 46 27
19	I.	,,	Last seen	,,	,,	23 47 23	
22	III.	,,	Began to fade	,,	,,	3 22 17	3 31 1
22	III.	,,	Last seen	,,	,,	3 36 14	
22	III.	Ecl. R.	First seen	,,	,,	5 5 5	5 8 20
22	III.	,,	Full brightness	,,	,,	5 17 8	
24	II.	Occ. R.	First seen	,,	,,	23 28 43	
24	II.	,,	Bisection	,,	,,	23 30 39	23 30
24	II.	,,	Last contact	,,	,,	23 32 14	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
April 27	I.	Tr. Ingr.	Ext. contact	8-inch	170	23 17 7	
27	I.	,,	Bisection	,,	,,	23 19 2	23 19
27	I.	,,	Int. contact	,,	,,	23 21 46	
28	I.	Occ. R.	First seen	,,	,,	22 48 10	
28	I.	,,	Bisection	,,	,,	22 48 58	22 50
28	I.	,,	Last contact	,,	,,	22 50 7	
May 1	II.	Ecl. D.	Last seen	,,	140	22 25 33	22 25 51
5	I.	,,	Began to fade	,,	,,	22 1 9	22 2 18
5	I.	,,	Last seen	,,	,,	22 3 3	
6	I.	Tr. Egr.	Ext. contact	,,	,,	21 41 47	21 41
13	I.	Tr. Ingr.	Int. contact	,,	,,	21 17 42	21 14
13	I.	Tr. Egr.	Int. contact	,,	110	23 20 47	
13	I.	,,	Bisection	,,	,,	23 22 36	23 25
13	I.	,,	Ext. contact	,,	,,	23 24 46	
17	II.	Tr. Ingr.	Ext. contact	,,	170	22 50 41	
17	II.	,,	Bisection	,,	,,	22 52 46	22 53
17	II.	,,	Int. contact	,,	,,	22 55 35	
18	II.	Tr. Egr.	Int. contact	,,	,,	1 14 7	
18	II.	,,	Bisection	,,	,,	1 16 7	1 19
18	II.	,,	Ext. contact	,,	,,	1 18 51	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
May 20	I.	Ecl. D.	Last seen	8-inch	130	1 50 45	1 50 9
20	III.	Occ. R.	Last contact	,,	95	21 7 36	21 3
20	I.	Tr. Ingr.	Ext. contact	,,	170	22 55 43	
20	I.	,,	Bisection	,,	,,	22 57 43	22 58
20	I.	,,	Int. contact	,,	,,	22 59 57	
21	I.	Occ. D.	First contact	4½-inch	120	20 15 54	
21	I.	,,	Bisection	,,	,,	20 17 39	20 17
21	I.	,,	Last seen	,,	,,	20 19 3	
21	I.	Occ. R.	Bisection	8-inch	170	22 26 49	22 28
21	I.	,,	Last contact	,,	,,	22 27 57	
June 9	II.	Occ. D.	First contact	,,	130	23 41 18	
9	II.	,,	Bisection	,,	,,	23 43 38	23 45
9	II.	,,	Last seen	,,	,,	23 46 12	
12	I.	Tr. Ingr.	Ext. contact	,,	,,	22 35 54	
12	I.	,,	Bisection	,,	,,	22 37 38	22 37
12	I.	,,	Int. contact	,,	,,	22 40 3	
13	I.	Occ. D.	First contact	,,	,,	19 54 10	
13	I.	,,	Bisection	,,	,,	19 55 49	19 55
13	I.	,,	Last seen	,,	,,	19 57 39	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
June 13	I.	Ecl. R.	First seen	8-inch	130	22 37 33	22 37 39
13	I.	,,	Full brightness	,,	,,	22 39 42	
14	III.	Tr. Egr.	Bisection	,,	,,	20 20 19	20 30
14	III.	,,	Ext. contact	,,	,,	20 31 42	
18	II.	Tr. Ingr.	Ext. contact	,,	,,	20 55 31	
18	II.	,,	Bisection	,,	,,	20 58 51	20 58
18	II.	,,	Int. contact	,,	,,	21 2 30	
18	II.	Tr. Egr.	Int. contact	,,	,,	23 22 7	
18	II.	,,	Bisection	,,	,,	23 25 36	23 26
18	II.	,,	Ext. contact	,,	,,	23 30 40	
21	I.	,,	Int. contact	,,	,,	20 56 31	
21	I.	,,	Bisection	,,	,,	20 58 56	21 2
21	I.	,,	Ext. contact	,,	,,	21 2 5	
21	III.	Tr. Ingr.	Ext. contact	,,	,,	21 59 16	
21	III.	,,	Bisection	,,	,,	22 8 14	22 10
21	III.	,,	Int. contact	,,	,,	22 17 43	
21	III.	Tr. Egr.	Int. contact	,,	,,	23 38 49	
21	III.	,,	Bisection	,,	,,	23 45 58	23 55
21	III.	,,	Ext. contact	,,	,,	23 54 47	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
June 22	I.	Ecl. R.	First seen	8-inch	75	19 0 57	19 0 41
22	I.	,,	Full brightness	,,	,,	19 2 45	
25	II.	Tr. Ingr.	Ext. contact	,,	170	23 16 1	
25	II.	,,	Bisection	,,	,,	23 18 6	23 15
25	II.	,,	Int. contact	,,	,,	23 20 21	
27	I.	Occ. D.	First contact	,,	—	23 25 25	
27	I.	,,	Bisection	,,	—	23 28 29	23 27
27	I.	,,	Last seen	,,	—	23 30 9	
2	III.	Ecl. D.	Began to fade	,,	75	19 6 53	19 12 5
2	III.	,,	Last seen	,,	,,	19 16 42	
2	III.	Ecl. R.	First seen	,,	,,	20 53 24	20 58 2
4	II.	Occ. D.	First contact	,,	170	19 50 14	
4	II.	,,	Bisection	,,	,,	19 52 23	19 53
4	II.	,,	Last seen	,,	,,	19 54 33	
July 5	II.	Ecl. R.	First seen	,,	130	0 16 14	0 15 34
5	II.	,,	Full brightness	,,	,,	0 20 39	
5	I.	Tr. Ingr.	Ext. contact	,,	170	22 23 22	
5	I.	,,	Bisection	,,	,,	22 25 17	22 24
5	I.	,,	Int. contact	,,	,,	22 27 27	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
July 7	I.	Tr. Egr.	Int. contact	8-inch	95	19 0 49	
7	I.	,,	Bisection	,,	,,	19 3 14	19 4
7	I.	,,	Ext. contact	,,	,,	19 6 8	
9	III.	Ecl. D.	Began to fade	,,	,,	23 3 29	23 10 53
9	III.	,,	Last seen	,,	,,	23 15 12	
10	III.	Ecl. R.	First seen	,,	,,	0 53 24	0 57 49
10	III.	,,	Full brightness	,,	,,	1 2 9	
11	II.	Occ. D.	First contact	,,	130	22 11 50	
11	II.	,,	Bisection	,,	,,	22 15 34	22 17
11	II.	,,	Last seen	,,	,,	22 18 49	
13	II.	Tr. Egr.	Int. contact	,,	,,	19 34 15	
13	II.	,,	Bisection	,,	,,	19 38 0	19 37
13	II.	,,	Ext. contact	,,	,,	19 41 54	
13	I.	Occ. D.	First contact	,,	,,	21 28 21	
13	I.	,,	Bisection	,,	,,	21 30 51	21 30
13	I.	,,	Last seen	,,	,,	21 32 30	
15	I.	Ecl. R.	First seen	,,	75	19 13 9	19 12 59
15	I.	,,	Full brightness	,,	,,	19 14 47	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
July 20	II.	Tr. Ingr.	Ext. contact	8-inch	130	19 35 8	
20	II.	,,	Bisection	,,	,,	19 36 58	19 31
20	II.	,,	Int. contact	,,	,,	19 40 8	
20	II.	Tr. Egr.	Int. contact	,,	,,	22 2 9	
20	II.	,,	Bisection	,,	,,	22 4 58	22 2
20	II.	,,	Ext. contact	,,	,,	22 8 23	
20	I.	Occ. D.	First contact	,,	,,	23 17 56	
20	I.	,,	Bisection	,,	,,	23 20 41	23 20
20	I.	,,	Last seen	,,	,,	23 22 45	
21	I.	Tr. Ingr.	Ext. contact	,,	,,	20 29 2	
21	I.	,,	Bisection	,,	,,	20 31 32	20 31
21	I.	,,	Int. contact	,,	,	20 34 41	
21	I.	Tr. Egr.	Int. contact	,,	,,	22 38 46	
21	I.	,,	Bisection	,,	,,	22 42 5	22 44
21	I.	,,	Ext. contact	,,	,,	22 45 19	
22	I.	Ecl. R.	First seen	,,	,,	21 7 24	
22	I.	,,	Full brightness	,,	,,	21 11 18	21 7 40

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Aug. 5	I.	Occ. D.	First contact	8-inch	130	21 29 17	
5	I.	,,	Bisection	,,	,,	21 32 41	21 31
5	I.	,,	Last seen	,,	,,	21 34 46	
5	II.	Occ. R.	First seen	,,	,,	21 32 11	
5	II.	,,	Bisection	,,	,,	21 33 21	21 33
5	II.	,,	Last contact	,,	,,	21 34 11	
5	II.	Ecl. D.	Last seen	,,	,,	21 37 50	21 39 10
6	II.	Ecl. R.	First seen	,,	,,	0 5 46	
6	II.	,,	Full brightness	,,	,,	0 7 25	0 5 2
6	I.	,,	First seen	,,	,,	0 56 55	
6	I.	,,	Full brightness	,,	,,	0 59 51	0 57 9
6	I.	Tr. Egr.	Int. contact	,,	,,	20 52 32	
6	I.	,,	Bisection	,,	,,	20 54 47	20 57
6	I.	,,	Ext. contact	,,	,,	20 57 26	
12	I.	Occ. D.	First contact	,,	140	23 23 12	
12	I.	,,	Bisection	,,	,,	23 25 16	23 24
12	I.	,,	Last seen	,,	,,	23 26 51	

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Aug. 13	II.	Occ. R.	First seen	8-inch	140	0 7 34	0 8
13	II.	,,	Last contact	,,	,,	0 9 29	
13	II.	Ecl. D.	Last seen	,,	,,	0 15 22	0 16 51
13	I.	Tr. Egr.	Int. contact	,,	,,	22 48 26	
13	I.	,,	Bisection	,,	,,	22 49 41	22 52
13	I.	,,	Ext. contact	,,	,,	22 51 36	
20	II.	Occ. D.	First contact	,,	,,	0 9 15	
20	II.	,,	Bisection	,,	,,	0 11 44	0 12
20	II.	,,	Last seen	,,	,,	0 13 14	
21	II.	Tr. Egr.	Int. contact	,,	,,	21 20 50	
21	II.	,,	Bisection	,,	,,	21 24 10	21 21
21	II.	,,	Ext. contact	,,	,,	21 27 39	
21	III.	Ecl. D.	Began to fade	,,	,,	22 57 54	
21	III.	,,	Last seen	,,	,,	23 7 15	23 3 47
21	I.	Ecl. R.	First seen	,,	,,	23 15 11	
21	I.	,,	Full brightness	,,	,,	23 17 51	23 15 24

Day of Obs. 1888.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
Aug. 22	III.	Ecl. R.	First seen	$4\frac{1}{2}$-inch	120	0 54 20	0 56 56
22	III.	,,	Full brightness	,,	,,	1 4 18	
Sept. 15	III.	Tr. Egr.	Bisection	8-inch	140	22 6 26	22 13
15	III.	,,	Ext. contact	,,	,,	22 11 50	
26	III.	Ecl. R.	First seen	,,	,,	20 54 59	20 57 32
26	III.	,,	Full brightness	,,	,,	21 5 33	
28	I.	Tr. Ingr.	Ext. contact	,,	230	21 19 37	21 21
28	I.	,,	Bisection	,,	,,	21 21 21	
28	I.	,,	Int. contact	,,	,,	21 22 56	
29	II.	,,	Ext. contact	,,	,,	21 30 52	21 29
29	II.	,,	Bisection	,,	,,	21 33 37	
29	II.	,,	Int. contact	,,	,,	21 35 37	
29	I.	Ecl. R.	First seen	,,	,,	21 46 39	21 46 39
29	I.	,,	Full brightness	,,	,,	21 49 29	
Oct. 1	II.	,,	First seen	,,	140	21 7 27	21 6 39
1	II.	,,	Full brightness	,,	,,	21 10 31	

Remarks.

1888, March 27.—Sky cloudless, but with full Moon; objects low and unsteady.

April 2.—Clear. Images steady and well defined.

April 9.—Clear; fair definition.

April 14, 15.—Cloudless. Bad definition at the disappearance, but good at reappearance.

April 19.—Clear; definition satisfactory.

April 22.—Clear. Images remarkably steady and well defined. Satellites dwindled to a mere point and then vanished. Time of full brightness perhaps too early.

April 24, 27.—Images steady and well defined.

April 28.—Images steady and pretty well defined; when first seen the projection of the satellite from the limb was rather conspicuous.

May 1.—Definition pretty good, but sky slightly hazy.

May 5, 6.—Sky clear, but planet boiling. Noted time of external contact probably rather early.

May 13.—Planet low and badly defined at ingress, but steady and well defined at egress.

May 17, 18.—Images steady and well defined.

May 20.—Sky clear. Satellite I., which was steady and well defined, did not at the eclipse come quite into contact with the limb, but as it disappeared it assumed an elongated form, the major axis of the oval lying parallel to the limb. Planet low at the occultation and boiling considerably. Images steady and well defined at the transit.

May 21.—Planet boiling at the disappearance; images steady and well defined at the reappearance.

June 9.—Images steady and definition pretty good.

June 12.—Poor definition.

June 13.—Clear. Images pretty steady and well defined.

June 14.—Clouds troublesome and definition bad.

June 18.—Definition fair at ingress, but very bad at egress.

June 21.—Definition satisfactory at all the phases, except at bisection of III. at egress.

June 22.—Clear sky and good definition, but twilight strong, the Sun's upper limb having disappeared below the horizon 14 minutes previously.

June 25, 27.—Very good definition.

July 2.—Clear, but twilight very strong at disappearance; good definition at reappearance.

July 4, 5.—Clear, with good definition. Satellite at eclipse suspected 12·5 seconds earlier.

July 7.—Strong twilight; images tremulous and badly defined.

July 9, 10.—Clear. Images steady and well defined. Satellite again glimpsed 17 seconds after recorded as last seen.

July 11.—Images steady and well defined.

July 13.—Definition fair, but images tremulous.

July 15.—Clear, with good definition, but twilight very strong.

July 20, 21.—Fair definition.

July 22.—Clear, with good definition, but moon very bright.

Aug. 5.—Definition good, but bisections rather late. Eclipse observation unsatisfactory owing to a filmy cloud.

Aug. 6.—Clear. Images well defined.

Aug. 12, 13.—Poor definition at occultation of satellite I. Observation of the reappearance of II. from occultation difficult in consequence of the faintness of the satellite, which was probably involved to some extent in the planet's penumbra. Fair definition at egress of satellite I.

Aug. 20.—Bad definition.

Aug. 21, 22.—Clear, and definition pretty good except at the reappearance

of satellite III. Satellites I. and III. suspected 14 and 3 seconds earlier than the respective recorded times. Full Moon.

Sept. 15, 26.—Images steady and well defined.

Sept. 28.—Bad definition.

Sept. 29.—Clear, with bad definition.

Oct. 1.—Definition pretty good, but sky slightly hazy. Full brightness very unsatisfactory.

It may be added that no occulting-bar has ever been employed in the eclipse observations made at this observatory from 1866 to the present time, and that the times given in the first and seventh columns of the accompanying table are the Windsor mean times of observation diminished by $10^h\ 3^m\ 20^s{\cdot}8$, and entered to the nearest second.

Windsor, N. S. Wales:
1889, *January* 8.

Request to Observers of Occultations. By John Tatlock, Jun.

(*Communicated by the Secretaries.*)

I should be obliged if those astronomers who secured observations of the occultation of α *Tauri* by the Moon, between the dates of 1884, September 10, and 1888, March 18, inclusive, will kindly send me copies of the records of such observations, together with full particulars essential to their reduction.

Care of North River Safe Deposit Company,
187 *Greenwich Street, New York.*

Report of the Work of the Melbourne Observatory during 1888. By R. L. J. Ellery, F.R.S.

During the year ending January 1, 1889, the meridian work with the transit-circle has been continued without interruption, and has included, besides the usual observations of the fundamental clock stars and close circumpolar stars, stars of the *Berliner Jahrbuch* which culminate sufficiently high to be well seen at Melbourne, stars to which the places of comets and small planets have been referred, and a list of stars selected by Dr. Gill for the reduction of his heliometer observations, as well as observations of *Iris* at opposition and a list of comparison stars; also to assist Dr. Gill. The number of R.A. observations was 3,154, and those for polar distance 1,571.

Very little work has been done during the year with the great reflector, on account of increasing tarnish of the mirrors, only 170 revisions of Herschel's nebulæ having been secured. Sixteen new nebulæ were catalogued, and three of Herschel's could not be found.

In June the telescope was dismantled and preparation made for repolishing the mirrors, involving a large amount of experimental work. One of the 4-foot mirrors was partially repolished in October, when it was found necessary to alter the arrangements of the machinery in order to facilitate testing the mirror-surfaces during the process of figuring and polishing. These alterations were not completed till midsummer, when the weather became too warm to continue the polishing with any prospect of success. Further work in this direction has therefore been deferred till after February.

Observations of Sawerthal's Comet (*a* 1888), of *Sappho* in April, and search for *Eucrate* in July and August were included in the extra-meridional work of the year.

Sun-pictures with the photoheliograph were obtained on 148 days only, as a considerable time was occupied in the alteration of the secondary magnifier to get rid of images of dust particles on the surface of the front lens which detrimentally disfigured the photographs.

The work in meteorology and terrestrial magnetism was continued as usual, including monthly determinations of the absolute elements of terrestrial magnetism and a continuous photographic register of variations.

The daily *Isobaric Chart of Australia and New Zealand* was issued regularly, as in former years.

A Meteorological Conference of the Directors of Australasian Observatories was held at the Melbourne Observatory in September, with the view of improving intercolonial meteorology, the following representatives attending:—H. C. Russell, B.A., F.R.S. (New South Wales); C. Todd, M.A., C.M.G. (South Australia); Hon. John Forrest, C.M.G. (Western Australia); Clement L. Wragge, F.R.G.S., F.R. Met. Soc. (Queensland); Capt. Shortt, R.N. (Tasmania); Sir James Hector, M.D., K.C.M.G. (New Zealand); Col. R. L. J. Ellery, F.R.S., F.R.A.S. (Victoria).

With the exception of the usual meteorological periodicals, no publications have been issued during the year. But the second *General Star Catalogue* and yearly *Catalogue of Separate Results of Transit Circle Observations for* 1880–85, to form vol. vii., will shortly appear.

A Seth Thomas precision clock was obtained in June last. Its performance so far has been very satisfactory.

Preparations are in progress for the erection of the photographic telescope now being constructed by Sir Howard Grubb for star-charting. The instrument will be similar to those being made by the same maker for Greenwich, Cape of Good Hope, Mexico, &c.

[The above Report arrived too late for insertion in the Annual Report of the Council.]